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The Value of U.S. Life Sciences

A White Paper Exploring Competitiveness, Delivery and Challenges

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with Ross DeVol

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Executive Summary

The life sciences industry in the United States is one of the country's greatest resources—and simultaneously one of its greatest puzzles. This field has given birth to some of the fastest-growing sectors of the U.S. economy, providing a tremendous amount of added value and high-level employment. But at the same time, the anxiety surrounding rising health-care costs has created a negative perception of the life sciences in the minds of many business leaders (even though much of the increase is actually driven by an aging and increasingly overweight populace and by inefficiencies and gaps in the nation's health insurance system).

A broader view of the life sciences sector reveals that a great opportunity exists for businesses not directly involved in the life sciences to benefit from the research and production strengths of this sector. We have undertaken here to demystify this industry and identify those opportunities.

The life sciences industry is one of the most significant value-added sectors of the knowledge-based economy within the United States. This field has generated tremendous growth over the past decade, a trend that continues even now. In an era when global competition has driven jobs overseas, this industry has consistently generated employment growth—and most important of all, growth in prestigious, high-wage, high-quality jobs. Key clusters of life sciences research have matured around locations such as Boston, Philadelphia, San Diego, San Francisco, and New York, creating vibrant regional economies. Beyond these traditionally strong centers, the life sciences industries are slowly spreading across the nation.

The United States is a global leader in life sciences—not only in terms of manufacturing but especially in research and development. Backed by world-class university research programs and a thriving venture capital community, the industry produces a steady stream of innovative pharmaceuticals, medical devices, and new treatments.

This tremendous R&D capacity should be recognized as one of the nation's most prized knowledge assets. The U.S. model in life sciences research is based on a synergy of government funding, research institutions, and private-sector investment and development. Significant investment opportunities exist for companies that are able to effectively partner in life sciences research.

Cutting-edge biomedical research has made the United States a hotbed of innovation, as a glance at the biotechnology industry shows.

Number of U.S. Issued Biotech Patents by Country

Ranked by Absolute Number, 2000–2004

Country	Absolute Number of Patents
United States	5446
Canada	301
United Kingdom	134
Austria	77
Israel	75
Japan	45
France	45
Netherlands	43
Belgium	30
Switzerland	18

Sources: IPIQ, Milken Institute

This snapshot of the top ten countries in biotech patents issued is extremely telling. The United States leads by a commanding margin—issuing seven times the number of biotech patents as the next nine countries combined. The success of the United States as a center of research, development, and manufacturing in the life sciences has set a compelling example for many other industries. The nation continues to attract and retain top research talent through a combination of government funding, partnerships between public and private research, and strong research clusters.

Even as the life sciences industry continues to develop new cutting-edge treatments, U.S. businesses are facing spiraling costs to ensure that their employees have continued access to quality health care. These rising costs can be attributed to a variety of factors, but we believe they can be addressed and somewhat mitigated through proactive strategies, including collaboration with the life science industry to implement better preventive care. Huge savings can be realized by reducing the nation's incidence of chronic disease—and as the nation searches for the most effective path to health-care reform, this strategy merits wider discussion and serious consideration.

As the table below listing the relative rates of chronic diseases in the United States vs. Europe reveals, Americans are diagnosed with major chronic diseases at a much higher rate that their European counterparts.

Comparison of Treatment Prevalence by Disease

U.S. and Europe, 2004

Disease	U.S. (%)	Europe (%)
Heart Disease	13.2	6.2
High Blood Pressure	44	29.3
High Cholesterol	19.1	12.3
Stroke/Cerebrovascular Disease	2.4	1.6
Diabetes	13.3	8.9
Chronic Lung Disease	5	1.5
Asthma	3.7	2.8
Arthritis	24.1	10.6
Osteoporosis	4.1	3.4

Source: Thorpe, Howard, Galactionova (2007)

These higher disease rates are caused by a number of factors, many of which are related to lifestyle. Increases in heart disease, high blood pressure, diabetes, and stroke are all directly correlated to the skyrocketing obesity rates in the United States. Creative and forward-thinking policies by corporations to encourage preventive care and promote healthier lifestyles among their employees could significantly reduce health-care costs on a national level.

While treatments exist for these conditions, and those options have improved greatly in recent years, there is room to make further strides. The tremendous capacity for ongoing innovation that characterizes the life sciences industry should be viewed as a major resource in the fight against these ailments. If the business community were to partner aggressively with the life sciences industry to focus squarely on an ambitious goal of reducing the most common chronic diseases, the results could include significant cost savings, higher productivity, and reduced human suffering. The U.S. life sciences industry has impressive human capital and world-class research capacity at its disposal; if we can effectively harness those capabilities, we can make headway in tackling the most pressing and costly health issues facing our nation.

Introduction

While a great deal of attention has been focused on the nation's increasing health-care costs, the value-added contribution of the life sciences industries to the U.S. economy is often overlooked. Through the active continuous development of new medical treatments to improve health and productivity, the life sciences industry generates high-wage jobs, powers regional high-tech economies, and attracts a substantial level of foreign investment for research and development into the United States.

This exploratory paper maps the competitiveness of the U.S. life sciences industry through a description of public and private financial support, international comparisons, and research and development processes. We propose a new view of the nation's life sciences industry: it should be considered as an accumulated wealth of strategic assets that can propel the U.S. economy in the decades to come.

The life sciences industry is made up of knowledge-driven and delivery sectors, including biotechnology, pharmaceuticals, medical devices, life sciences R&D, and health-care services. While it is important to ensure a strong innovation pipeline to create and commercialize new innovation and discoveries in these industries, it is also critical to assess the quality of health-care delivery, which has indirect but major implications on the nation's economy. Thus we will extend our analysis to describe the state of the nation's health-care services, which are faced with addressing an increasing burden of chronic diseases. We believe that while disease prevalence and high health-care costs are currently inhibiting productivity, the United States can rectify this situation by more fully deploying its life sciences R&D assets to address these issues, paving the way for enhanced economic growth. The innovation capacity inherent in this field is the strongest tool at our disposal as we look to solve America's health-care crisis.

The life sciences innovation system in the United States is driven by a unique set of collaborations by diverse agents, ultimately creating a competitive market for research and development (R&D). Public organizations such as universities and institutes partner with private firms in dense regional life science clusters. The cross-disciplinary research made possible by these alliances has created a fertile environment for innovation.[1] New developments move through technology-transfer and commercialization linkages in a dynamic process. Strong policy frameworks, dating back to the 1980s, have facilitated this technology-transfer process so successfully that they have positioned the United States as a global leader in life sciences. It is vital that businesses collaborate closely with R&D institutions, universities, and the government to enhance this leadership position, which should be recognized as one of our nation's greatest competitive advantages in the global marketplace.

We begin by providing an overview and definition of the life sciences industry before exploring the U.S. innovation pipeline in detail and mapping the private and public funding sources for life sciences. (Because of the limited scope of this report, we have largely focused on private sector investment in the form of venture capital, but it is important to note that VC represents only one stream of private-sector funding.) In section five, we will examine the global competitiveness of the United States in this knowledge-intensive arena. In sections six and seven, we move to the delivery component of the life sciences industry, where we will discuss the burden of chronic diseases in the United States and how they exacerbate the rising costs of health-care services. We will also explore how corporations can mitigate such costs through effective planning and direct partnerships with health-care firms.

This exploratory paper concludes by summarizing the value of the life sciences industry in the United States and the challenges we must overcome to sustain global leadership in this field. Focusing on these opportunities will be the key to developing more productive links among innovation, commercialization, and health care—ultimately resulting in a healthier and more prosperous nation.

1. Defining the Life Sciences

The life sciences and the associated health-care industries are the fastest-growing broad sector of the U.S. economy. Life sciences involve the study of living organisms, in fields such as bioengineering, pharmacogenomics, and nanomedicine. The industry as a whole has proven to be a strong economic engine, creating millions of jobs, many of which pay above-average salaries. Furthermore, the industry's end products lead to better health, which is an intangible economic asset.[2]

Given the industry's growing importance, life science clusters have become undisputed engines of economic growth. Flows of capital to finance research are reinvested through wages and subsequent spending. Since workers in this sector command high wages, regions with major concentrations of life sciences activity enjoy higher-than-average incomes and greater wealth.[3] In this paper, we argue that life sciences innovation industries, including health-care service providers, exist in an opportunistic market that can further enhance U.S. leadership on the global stage.

North American Industry Classification System Codes

Using the North American Industry Classification System (NAICS), the life sciences industry can be defined in the following two tables. We have separated the industry into two major categories: therapeutics and devices, and health-care services. This distinction allows us to differentiate the knowledge-intensive manufacturing sector that produces innovation from the service-oriented sector that applies these innovations to outputs. Using these six-digit level NAICS codes achieves the specificity required to avoid cross-industry categorization. In other words, these codes are life sciences–specific.

NAICS	Life Sciences Industry Group
325411	Medicinal and Botanical Manufacturing
325412	Pharmaceutical Preparation Manufacturing
325413	In-Vitro Diagnostic Substance Manufacturing
325414	Other Biological Product Manufacturing
339111	Laboratory Apparatus and Furniture Manufacturing
339112	Surgical and Medical Instrument Manufacturing
339113	Surgical Applicance and Supplies Manufacturing
339114	Dental Equipment and Supplies Manufacturing
339115	Ophthalmic Goods Manufacturing
339116	Dental Laboratories
334510	Electromedical Apparatus Manufacturing
334517	Irradiation Apparatus Manufacturing
5417102	R&D in Life Sciences

Definition of Life Sciences Health Care Services

NAICS	Life Sciences Industry Group
621111	Offices of Physicians (except Mental Health Specialists)
621112	Offices of Physicians, Mental Health Specialists
621210	Offices of Dentists
621310	Offices of Chiropractors
621320	Offices of Optometrists
621330	Offices of Mental Health Practitioners (except Physicians)
621340	Offices of Physical, Occupational and Speech Therapists, and Audiologists
621391	Offices of Podiatrists
621399	Offices of All Other Miscellaneous Health Practitioners
621410	Family Planning Centers
621420	Outpatient Mental Health and Substance Abuse Centers
621491	HMO Medical Centers
621492	Kidney Dialysis Centers
621493	Freestanding Ambulatory Surgical and Emergency Centers
621498	All Other Outpatient Care Centers
621511	Medical Laboratories
621512	Diagnostic Imaging Centers
621610	Home Health Care Services
621910	Ambulance Services
621991	Blood and Organ Banks
621999	All Other Miscellaneous Ambulatory Health Care Services
622110	General Medical and Surgical Hospitals
622210	Psychiatric and Substance Abuse Hospitals
622310	Specialty (except Psychiatric and Substance Abuse) Hospitals
623110	Nursing Care Facilities

2. The Engine of the Life Sciences in the United States

Leading Life Sciences Centers

In the United States, commercial research constitutes a large component (approximately 25 percent) of the life sciences industry.[4] Several locations around the country have built entire high-tech economies around their knowledge assets. This section provides an overview of these regions and the comparative advantages they provide, not only for firms within the life sciences but also for other research-intensive companies.

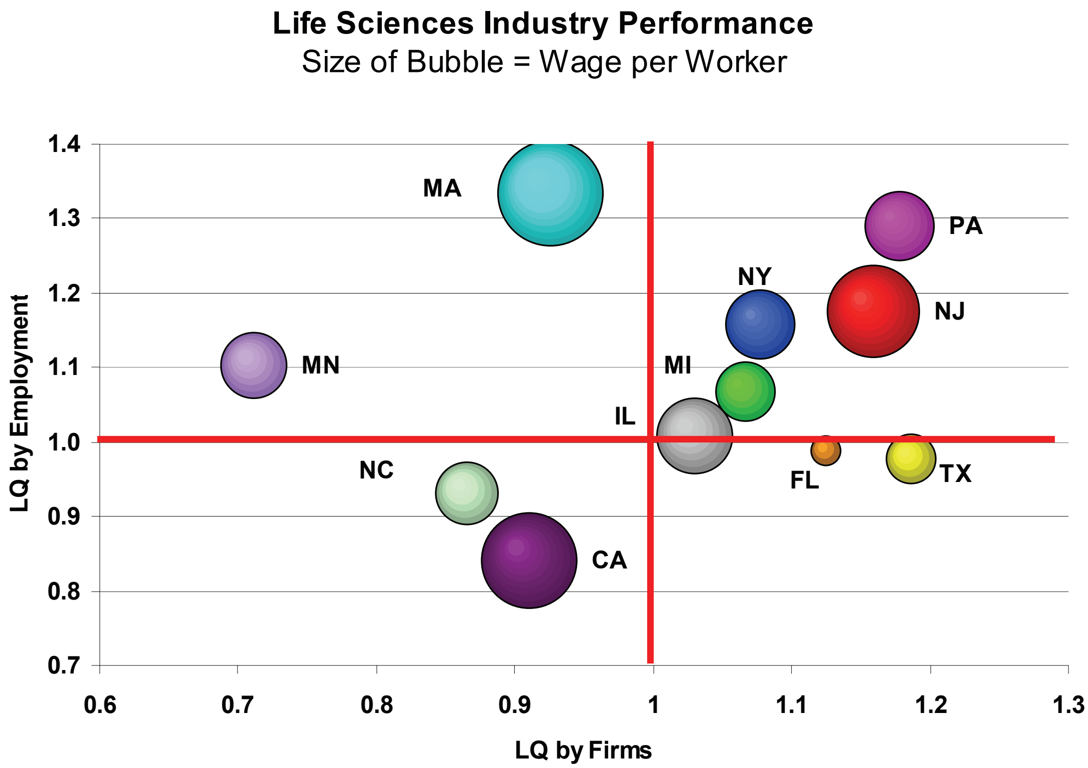
Where Are the Leading Life Sciences Regions?

In terms of life sciences employment, Massachusetts and Pennsylvania are ranked as top states, led by strong centers of research and innovation in Boston and Philadelphia, respectively. The Greater Boston area is one of the most competitive hubs for the life sciences industry, with a high concentration of workers with advanced degrees and a vibrant foundation of medical-device companies.[5] Similarly, the Greater Philadelphia region is a powerhouse, with top research universities, such as the University of

Pennsylvania, boosting its R&D capabilities.[6]

Outstanding life science clusters also exist in California, which boasts a concentration of leading pharmaceutical and biotech firms. In addition, the University of California (UC) system is a major player in life science innovation. The UC system leads its peers around the world in R&D and produces a wealth of patents and publications. Between 1998 and 2002, three UC universities (UC–San Francisco, UC–Los Angeles, and UC–San Diego) ranked within the top ten universities globally in producing biotechnology publications. (In fact, with the exception of the University of Tokyo, which was ranked second, the other top ten positions were occupied by U.S. universities, including first-place Harvard University in Massachusetts and the fifth-place University of Pennsylvania.[7]) Possibilities exist in each of these states for corporations to broaden access to treatment programs for their employees, and to work with leading health-care innovators to design and provide a higher overall quality of care.

The performance of life sciences industries of key states is illustrated in the following figure. The horizontal axis depicts the concentration of life sciences firms with respect to the average across the entire United States. The vertical axis shows the concentration of life sciences workers, referred to as "location quotients" (LQ), when compared to the national average. The location quotient reflects the employment concentration of a particular industry in a region relative to the rest of the nation. The sizes of the bubbles in the following figure represent the relative wages per life sciences worker.



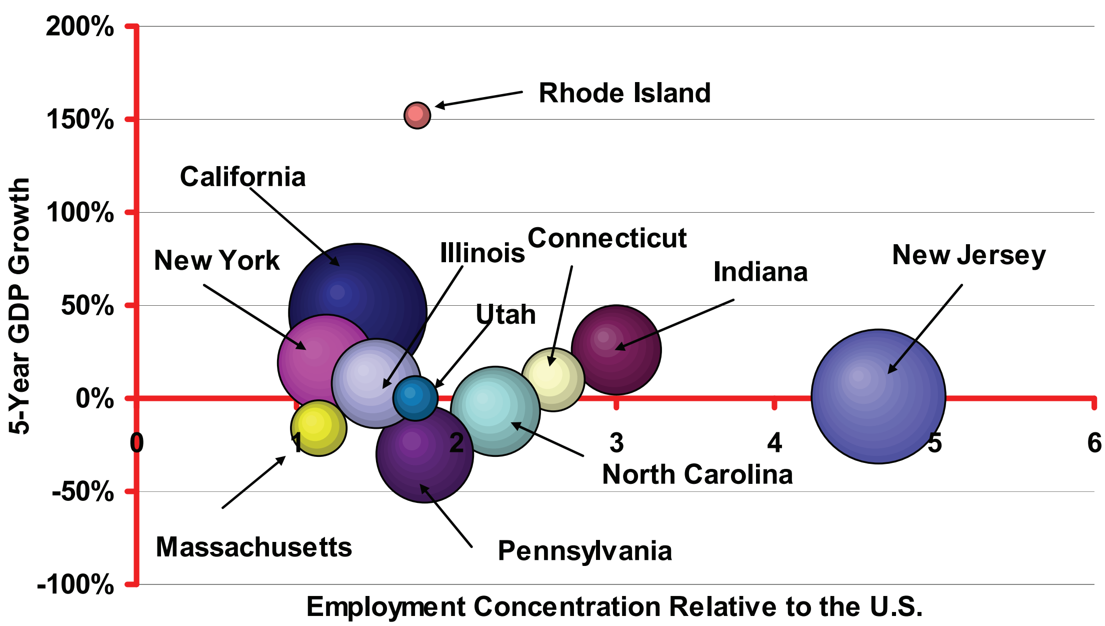
This illustration shows that Massachusetts offers the highest wages to life sciences workers. While the state has a major concentration of such workers, it does not, however, have a substantial concentration of life sciences firms—in fact, it comes in below the U.S. average of 1.0. The life sciences industry in California has the same characteristics, although unlike Massachusetts, its worker concentration is below the national average. This could be due to the presence of other major industries such as agriculture. Additionally, California's strength is in biotechnology, not in high-employment sectors such as health-care services. This means that the life sciences industry in Massachusetts is dependent on a small number of large firms, while California's is even further concentrated on a small proportion of workers.

Leading Biotech and Pharmaceuticals Industries

Looking specifically at the biotech and pharmaceuticals industries, twelve states had employment concentrations above the U.S. average in 2006. These states each offer potential opportunities for investments in life science start-up firms due to their pools of both research and skilled human capital. Although California and Massachusetts made this list, their employment concentrations ranked as tenth and twelfth, respectively. In addition, Massachusetts posted negative five-year growth in biotech and pharmaceuticals, indicating problems in creating, attracting, and retaining high levels of employment at these firms. New Jersey took the lead in terms of employment concentration, although its five-year growth was stagnant. Incidentally, California still maintains its robust industry base, with the highest absolute number of workers in the biotech and pharmaceutical industry. As biotechnology is often considered to be a leading source of innovation and growth in the life sciences, states that are strong in the field should be considered to have a comparative advantage in developing and growing their life sciences position.

Top 12 States in Biotech and Pharmaceuticals Industry

Size of Bubble = Total Biotech and Pharmaceuticals Employment



Analyzing Life Sciences Leadership in the United States

The Importance of Universities

Those states with particularly robust life sciences industries have one thing in common: They all have top research universities in significant clusters to spark innovation. The excellence of these universities is undoubtedly a key to U.S. global leadership in this field. Cooperation with universities—both in terms of research as well as in technology transfer—is a vital component of in America's current leadership position in the life sciences. This model also works well in other knowledge-based and high-technology industries.

Innovation (or R&D) is a defining characteristic of this sector. Life sciences industries thrive in regions that have institutions and policies in place that effectively transfer technologies from universities to the commercial marketplace; that process is central to creating a robust regional industry. The following chart shows the concentration of life sciences R&D in key metropolitan regions. (We have studied metropolitan regions instead of states, since R&D activities tend to be concentrated within tight regional clusters instead of spread widely across states.)

The presence of universities is therefore, a crucial factor in promoting growth in a knowledge-based regional economy. Universities play important roles in R&D as well as technology transfers, which bring scientific innovation to commercialization. The following table provides a summary of biotech rankings among international universities. The results show that the United States is a global leader in academic biotech research, with thirty-five of its universities among the top fifty positions. That enviable knowledge base translates directly into leadership in the life sciences. The role of universities in technology transfer is significant in numerous fields outside the life sciences, but the tremendous growth created in this sector by universities raises opportunities for numerous businesses, even those only marginally aligned with the life sciences. Firms in other industries can follow the model forged by the life-science industry to develop closer and more productive working relationships with university researchers. The ability to partner with universities' technology-transfer offices and to seek out broader industrial applications for technologies developed in fields such as biotech and medical devices is an important resource that should not be squandered. In the Tampa Bay region, for example, the Florida High-Tech Corridor has established grant-matching programs with neighboring universities, including the University of Central Florida, the University of Southern Florida, and the University of Florida.[8] These collaborative efforts reflect the combined regional efforts of different organizations to boost overall R&D and tech-transfer success.

Milken Institute Biotechnology University Publication Ranking

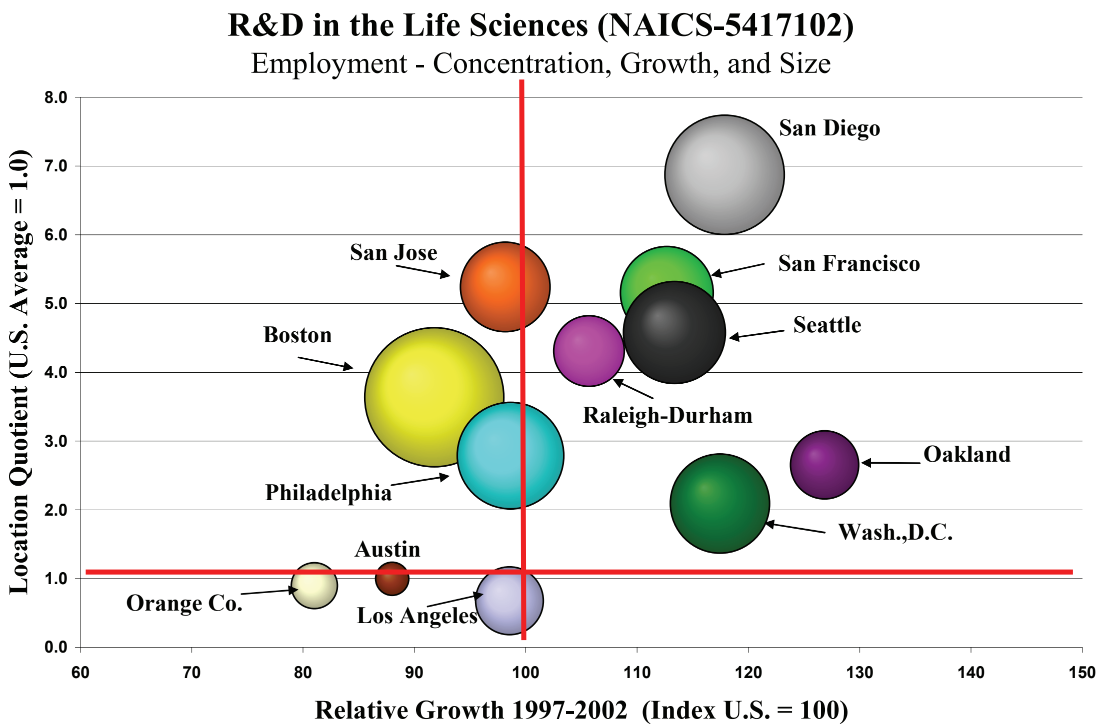
Percent Share of Biotech Publications by University, Top 50, 1998 to 2002

Rank	University	Country	Total Univ. Publ.	Total Biotech Publ. by Univ.	% Share Biotech Publ.
1	Harvard University, Cambridge	USA	58,563	11,098	19%
2	University of Tokyo	Japan	53,711	9,418	18%
3	University of London	UK	76,143	9,633	13%
4	University of California, San Francisco	USA	26,017	6,049	23%
5	University of Pennsylvania, Philadelphia	USA	31,982	5,745	18%
6	University of California, San Diego	USA	23,688	4,657	20%
7	Johns Hopkins University, Baltimore	USA	32,783	5,277	16%
8	Washington University, St. Louis	USA	18,527	4,202	23%
9	University of Washington, Seattle	USA	34,266	5,230	15%
10	University of California, Los Angeles	USA	36,204	5,215	14%
11	Yale University, New Haven	USA	22,733	4,167	18%
12	Stanford University	USA	25,279	4,208	17%
13	Rockefeller University, New York	USA	3,574	1,560	44%
14	University of Wisconsin at Madison	USA	23,543	3,897	17%
15	University of Cambridge	UK	23,994	3,843	16%
16	Baylor College of Medicine, Houston	USA	13,452	3,388	25%
17	University of Oxford	UK	21,331	3,526	17%
18	Duke University, Durham	USA	20,516	3,492	17%
19	Osaka University	Japan	31,257	4,821	15%
20	Kyoto University	Japan	27,618	4,630	17%
21	Massachusetts Institute of Technology (MIT), Cambridge	USA	18,293	3,044	17%
22	University of Texas at Dallas	USA	10,929	2,867	26%
23	Universités de Paris (I - XIII)	France	43,791	5,368	12%
24	Columbia University, New York	USA	24,723	3,554	14%
25	University of California, Berkeley	USA	25,408	3,598	14%
26	Case Western Reserve University, Cleveland	USA	13,612	2,852	21%
27	Cornell University, Ithaca	USA	23,100	3,579	15%
28	University of North Carolina at Chapel Hill	USA	20,109	3,095	15%
29	Yeshiva University	USA	10,148	2,300	23%
30	University of Toronto	Canada	35,108	4,538	13%
31	McGill University, Montreal	Canada	18,846	3,348	18%
32	University of Michigan, Ann Arbor	USA	30,021	4,047	13%
33	Vanderbilt University, Nashville	USA	13,403	2,871	21%
34	University of Iowa, Iowa City	USA	15,519	2,712	17%
35	Karolinska Institutet, Stockholm	Sweden	22,212	3,403	15%
36	University of Medicine and Dentistry (UMDNJ), New Brunswick	USA	18,181	2,926	16%
37	University of Alabama at Birmingham	USA	12,676	2,564	20%
38	State University of New York (SUNY) at Stony Brook	USA	8,745	1,711	20%
39	Université de Genève	Switzerland	9,760	1,412	14%
40	University of Wales, Aberystwyth	UK	1,275	54	4%
41	New York University (NYU)	USA	14,748	2,343	16%
42	University of Utah, Salt Lake City	USA	11,074	2,171	20%
43	Universität Basel	Switzerland	6,699	1,159	17%
44	University of Chicago	USA	16,837	2,566	15%
45	University of Massachusetts at Amherst	USA	10,522	1,791	17%
46	University of Dundee	UK	4,362	1,121	26%
47	Oregon Health & Sciences University, Portland	USA	7,217	1,366	19%
48	University of Edinburgh	UK	11,397	1,918	17%
49	Universités de Strasbourg (I - III)	France	9,653	1,486	15%
50	Universität Zürich	Switzerland	12,243	1,933	16%

Sources: Center for Science and Technology Studies (CEST); Thomson Scientific (SCI/SSCI/AHCI); Milken Institute

Fueling Leadership Through R&D

In the following chart, the horizontal axis shows the growth of the R&D sector of the industry relative to the national average, while the vertical axis depicts the concentration of life sciences workers relative to the U.S. average. The sizes of the bubbles represent the relative size of R&D employment in the industry.



Boston has the highest absolute number of life sciences workers, with a concentration higher than the U.S. average. San Diego's life sciences R&D industry has the best growth performance. Not only did the region have the greatest number of life sciences workers, but it also had the highest concentration and the second-highest relative growth.

Patents reflect the output from R&D. The United States produced a higher absolute number of biotech patents than any other country from 2000 to 2004. With 5,446 patents, the nation dominated global life sciences innovation. Canada and the United Kingdom came in at second and third places, but with only 301 and 134 patents, respectively. The following chart shows the absolute number of patents produced on a national level between 2000 and 2004.

Number of U.S. Issued Biotech Patents by Country

Ranked by Absolute Number, 2000–2004

Country	Absolute Number of Patents
United States	5446
Canada	301
United Kingdom	134
Austria	77
Israel	75
Japan	45
France	45
Netherlands	43
Belgium	30
Switzerland	18
Germany	17
Singapore	14
Korea, Republic of	13
Finland	12
China	11
Ireland (NI+IE)	11
Spain	9
India	8
Hong Kong SAR	5
Italy	5
Brazil	4
Portugal	4
Costa Rica	3
Mexico	3
New Zealand	2
South Africa	2
Thailand	1
Taiwan	1
Mali	1
Cuba	1
World Total	6341

Sources: IPIQ, Milken Institute

The issuance of patents in the United States has not always been high. Prior to 1981, American universities were issued fewer than 250 patents annually.[9] However, in 1996, this number soared to more than 1,200. In 2004, U.S. universities were granted 2,300 patents. An increasing number of these institutions are following up their patents with further research.

U.S. leadership in terms of the number of patents—and indeed in the overall life sciences industry—can be attributed to the nation's culture of ingenuity and its robust innovation pipeline. Life sciences research in the United States is conducted by a close but broad network of stakeholders. While much of this cutting-edge research is driven by the R&D operations of major corporations, small firms also play important roles in life sciences development.[10] Activities of public research organizations and small firms are linked by connections among therapeutic areas and stages of development. By contrast, European life sciences R&D involves small networks of establishments working on similar problems.[11] These deep connections in the United States have produced a strong foundation for continued innovation and leadership. The leading role of life sciences R&D helps to create a critical mass of research firms and funding—an infrastructure that is also available to firms that are not directly a part of the life science industry.

A Strong Policy Framework

The United States has been able to nurture its life sciences R&D leadership thanks to a national policy framework that fosters innovation. The nation has had a long history of actively developing its R&D capabilities. In 1980, two bills were passed by Congress to facilitate the commercialization of publicly funded intellectual property by private firms. With these in place, researchers and scientists were able to license technologies and create spin-off companies from the public sector. The Bayh–Dole University and Small Business Patent Act was enacted to permit nonprofit organizations, universities, and small businesses to retain ownership title to inventions that resulted from federal grants and contracts. The Stevenson–Wydler Technology Innovation Act (subsequently amended by the Federal Technology Transfer Act of 1986) facilitated the transfer of technologies from the public to the private sector.[12]

In recent years, the U.S. government increased intellectual property (IP) enforcement capabilities and stressed the global protection of IP rights in trade negotiations.[13] These moves enhance the technology-transfer mechanism in the United States and facilitate a more vibrant life science innovation pipeline.

It may be useful to consider a contrasting example. During the 1980s and most of the 1990s, Korean universities did not play a major role in nurturing the country's technologies. Korean companies wishing to obtain new technologies had to procure them from foreign sources. The nation's economy was dominated by four family-owned conglomerates: Hyundai, Samsung, LG, and SK Group, all of which receive tremendous support from the government. This changed after the financial crisis in 1997, with the introduction of new policies to encourage business ventures.[14] The turn of the millennium marked changes in the government's efforts to develop its life sciences industry. In 2002, the Korean government invested $14.4 billion in biotechnology.[15] These changes sought to build a more robust and closely-knit R&D climate, and have been beneficial to the national economy. Between 2000 and 2005, the country's biotechnology industry grew rapidly from US$1.2 billion to US$2.71 billion. Biotechnology remains a key industry in South Korea, and is expected to grow to US$6.5 billion by 2010.[16]

A Closer Look at the U.S. Innovation Pipeline

The "innovation pipeline" refers to the support infrastructure and outcome measures that allow a nation or region to actually capitalize on its strengths in knowledge and inventiveness, parlaying scientific discoveries into tangible products and services. A rich innovation pipeline plays an important part in making the life sciences competitive and sustaining their long-term growth. It also constitutes an important asset in its own right.

While the private sector drives a great deal of this process, universities also play a major role in life sciences research. They support the innovation system that forms the backbone of sustainable regional scientific clusters.[17] In this regard, the United States made tremendous strides. As mentioned above, U.S. universities developed fewer than 250 patents annually prior to 1981.[18] But by 1996, universities received more than 1,200 patents yearly, and then in 2004, this number soared beyond 2,300.[19] Between 2001 and 2006, patent filings in biotechnology have increased by 46 percent, while those related to pharmaceuticals and chemicals rose by roughly 42 percent.[20] While recent years have brought remarkable success at the research level, increased delays at the U.S. Patent Office (USPTO) are inhibiting the process of moving from innovation to commercialization.[21]

Nonetheless, the decentralized system of innovation that prevails in the United States allows for research independence. Increased competition and a healthy mixture of basic and applied research have led to exciting cross-disciplinary collaborations. Scientists can move fluidly across establishments, crossing between academia and the private sector.

This flexibility has fostered an R&D environment that produces a high rate of commercialization in life sciences.

European universities, by contrast, have centralized financing systems that lead to greater hierarchical control. The relative lack of flexibility that results from that structure inhibits the life sciences innovation system.[22] Similarly, many countries in Asia have developed a more centralized system of innovation. Singapore's policy framework, for example, is built around publicly owned universities. Entrepreneurship and new advances are influenced by direct push and involvement from the government. In Japan, technology transfer from universities is a relatively new phenomenon without the long track record that has been established in the United States. Technology licensing offices were only established in 1998.[23] In the same year, the first four offices of technology transfer were approved at the University of Tokyo, Nihon University, Kansai OTT (jointly constituted by Kyoto and Ritsumeikan Universities, among others), and Tohoku Techno Arch Co. Ltd. (constituting Tohoku University and other universities in the Tohoku region).[24] These differing cultures have made the U.S. life sciences industry more attractive to investors.

The presence of elite medical schools within regional life sciences clusters such as those in Philadelphia, Boston, and San Diego enhance the quality and productivity of life sciences innovation in the United States. Following these successful models, Orlando recently established a new College of Medicine at the University of Central Florida, which is poised to deliver a projected $1.4 billion regional economic impact through wages, employment, and output generated by the tenth year of its existence.[25]

The following table delineates the life sciences innovation pipeline matrix developed by the Milken Institute. There are five broad metrics: R&D presence, innovation output, risk capital and entrepreneurial infrastructure, human capital, and workforce. Each represents an important facet of a region's innovation pipeline. The operationalization of each metric is given in the corresponding right column.

Innovation Pipeline Matrix of Analysis

Metric	Description	Operationalization
R&D Presence	The presence of cutting-edge R&D is essential to a region's ability to commercialize innovation. This transfer process is carried out by universities, institutes, and firms facilitated by R&D funding. The transfer success, along with awards received, reflects the quality of these innovations in a given region.	NIH funding to independent hospitals
		Industry R&D to life sciences
		Academic R&D to life sciences
		NSF research funding
		STTR awards to life science firms
		STTR awards measured by dollar amounts
		SBIR awards to life science firms
		SBIR awards measured by dollar amounts
		Competitive NSF funding rate in life sciences
		NIH funding to medical schools
		NIH funding to research institutes
Innovation Output	This component captures the ability of a region to leverage its life sciences assets. Innovation output is dependent on new drug development, and approval and commercialization processes, which are often long and expensive.	FDA drug approval
		FDA new medical devices premarket approval
		Clinical trials (Phase I)
		Clinical trials (Phase II)
		Clinical trials (Phase III)
		Life sciences patents issued
		Weighted life sciences patent growth percentage
		Weighted percentage of life sciences patents in area
		Current Impact Index (CII): number of cited patents
		Weighted life sciences technology strength
		Weighted life sciences technology cycle time
		Weighted life sciences science linkage
		Weighted life sciences strength
Risk Capital and Entrepreneurial Infrastructure	Startups, key companies, and entrepreneurs constitute the entrepreneurial infrastructure. Venture capital is essential to business development and growth.	Early-stage seed capital
		Life sciences VC investment
		Life sciences VC investment growth
		Life sciences VC investment to companies
		Growth in companies receiving life sciences VC investment
		Business starts in life sciences
		Academic degrees awarded in entrepreneurship
		Number of Tech Fast 500 companies in life sciences
Human Capital Analysis	The ability of a region to excel in knowledge-intensive sectors depends on its capacity to produce a highly skilled work force.	Number of life sciences Ph.D.-granting institutions
		Number of life sciences bachelor's degrees awarded
		Number of life sciences graduate students
		Number of life sciences master's degrees awarded
		Number of life sciences Ph.D.s awarded
		Number of medical doctor degrees
		Number of life sciences postdoctorates
		Recent bachelor's degrees awarded in life sciences
		Recent master's degrees awarded in life sciences
		Recent Ph.D.s awarded in life sciences
		Recent medical doctor degrees awarded
Workforce Analysis	The competitive advantage of a region's knowledge industry is dependent on its ability to leverage talent to support the commercialization and production of innovation.	Intensity of biomedical engineers
		Intensity of medical and health services managers
		Intensity of chemical engineers
		Intensity of materials engineers
		Intensity of electro-mechanical technicians
		Intensity of biochemists and biophysicists
		Intensity of microbiologists
		Intensity of medical scientists, except epidemiologists
		Intensity of chemists
		Intensity of materials scientists
		Intensity of biological technicians
		Intensity of chemical technicians
		Intensity of sales representatives, wholesale and manufacturing, technical, and scientific products

Looking below at key individual states, we see that Massachusetts and California again rank among the top five in all measurements of their life sciences innovation pipelines (with the exception of California's human capital ranking, which surprisingly came in at only seventh in the nation, behind states such as Massachusetts, Pennsylvania, New York, and Illinois).

Breakdown of Innovation Pipeline Analysis

	Life Sciences R&D		Risk Capital		Human Capital		Workforce Composition		Innovation Output	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
MA	100.00	1	94.51	2	100.00	1	99.33	2	100.00	1
CA	95.97	2	100.00	1	93.11	7	100.00	1	93.74	2
PA	87.08	3	77.88	5	99.43	2	32.21	4	76.92	8
NY	86.24	4	56.52	20	98.04	3	91.11	5	75.64	9
NJ	82.65	7	77.91	4	88.25	15	95.38	3	91.08	3
NC	82.09	9	68.94	12	86.95	18	87.08	7	66.78	12
IL	79.10	12	62.92	13	94.81	4	83.94	9	68.89	11
TX	76.78	15	69.51	10	84.36	24	84.81	8	63.16	15
MN	74.14	17	76.02	6	86.65	19	80.63	13	82.19	5
FL	72.70	19	59.34	17	83.33	27	76.44	16	63.58	14
MI	71.02	20	60.43	14	90.70	9	70.10	22	55.02	24

The Milken Institute's University Technology Transfer and Commercialization Index measures the capability of universities to commercialize the intellectual property they develop. According to the index, which is based on data from 2000 to 2004, the University of California (UC) system ranked second in terms of patents issued, licenses executed, licensing income, and start-ups. The top position went to the Massachusetts Institute of Technology (MIT). However, the third and fourth places went to the California Institute of Technology and Stanford University, both within the state of California. Among the top ten positions in this index, the University of British Columbia in Canada was the only non-U.S. university. This again suggests strong U.S. capabilities for technology transfer. The following table provides a summary of the results.

Milken Institute University Technology Transfer and Commercialization Index

2000–2004

Rank	Institution Name	Country	Patents Issued Score	Licenses Executed Score	Licensing Income Score	Startups Score	Overall Score
1	Massachusetts Inst. of Technology (MIT)	U.S.	95.17	79.89	90.64	100.00	100.00
2	University of California System	U.S.	97.26	85.25	95.16	83.24	96.59
3	California Institute of Technology	U.S.	100.00	70.77	87.12	86.60	92.94
4	Stanford University	U.S.	91.56	84.28	93.76	77.02	92.65
5	University of Florida	U.S.	84.82	71.41	92.57	69.26	86.11
6	University of Minnesota	U.S.	78.92	77.46	91.02	69.24	85.55
7	Brigham Young University	U.S.	66.87	80.60	86.13	77.57	85.41
8	University of British Columbia	Canada	74.36	74.09	82.73	77.42	84.23
9	University of Michigan	U.S.	82.70	72.25	77.98	74.89	82.54
10	New York University	U.S.	73.68	63.30	100.00	58.16	81.63

Sources: AUTM, Milken Institute

Given that California is extremely successful in raising private capital and government funding in the life sciences, it is surprising to note that the state does not perform as well in measurements of human capital. However, in terms of innovation output, California ranks second behind Massachusetts, suggesting that while fewer Californians hold advanced degrees in the life sciences, the state is more productive in terms of R&D commercialization. Massachusetts has slower life sciences job growth and less venture capital directed at commercializing university-derived biotech research as compared to California.[26] This may represent an opportunity for increased private capital and public funding.

Indeed, California ranked first in terms of risk capital and entrepreneurial infrastructure. Despite the state's number-seven ranking for human capital (holders of advanced degrees in these fields), California also has the highest rank in life science work force. A high concentration of educated people is a defining characteristic of innovation centers.[27] This explains why Massachusetts has the highest concentration of advanced degrees and innovation output and a strong performance in life sciences R&D. These strengths lay the foundation for private capital investments and industrial commercialization. In the next section, we turn to the role of private capital in the life sciences.

3. Private Sector Support: Private Capital Alters the Landscape of the Life Sciences

Entrepreneurial capacity and performance drive today's economy. Creativity and innovative dynamics can determine the competitive advantage of a firm and even an entire industry. Risk capital and entrepreneurs play a pivotal role, since new firms and spin-offs are the best breeding grounds for new ideas.

The United States is a world leader in the availability of venture capital (VC). VC firms usually specialize in specific industries, and they have a tendency to gravitate toward fast-growing clusters. In turn, the founders of successful start-up firms become investors who finance others in the industry.[28] U.S. life science centers have a strong appeal to venture capitalists.

Venture capital funding for biotechnology research has shown steady growth. In 2004, the biotechnology industry raised more than $20 billion in debt and equity capital. Traditional pharmaceutical firms, such as Eli Lilly and Company, have also created their own VC funds to invest in biotech firms.[29] The intensity of investment strategizing to further develop the life sciences industry varies across the United States. California, New

Jersey, Massachusetts, and Pennsylvania continue to lead the way as they enhance their existing regional centers and clusters.[30]

In contrast, between 1990 and 1994, there were no biotechnology investments in Japan. The nation's Science and Technology (S&T) Basic Plan was introduced in 1999, leading to $1.2 million of VC investments in biotechnology and only accounting for 2 percent of the country's total biotechnology portfolio. However, this funding increased to $13 million (5 percent of the total portfolio) by 2000.[31]

We will focus our discussion of entrepreneurial capacity and performance on venture capital investments and start-ups, as well as anchor firms. The former highlights the degree to which innovations lured investments, highlighting the economic value of innovation to a given region. The latter shows the assets resulting from entrepreneurial performance in a region. These two indicators illustrate the impact of life sciences–related private capital in the United States.

Building Capital for the Life Sciences

State and local governments across the United States are developing technology initiatives in a bid to attract domestic and foreign investments. More than 40 states have announced efforts to enhance local and regional development of their respective life sciences industries. For example, in 1999, Michigan announced a spending initiative of $50 million per year over a span of 20 years to build a life sciences corridor. In the Mid-Atlantic region, "Innovation Philadelphia" is a public-private collaboration that was launched to promote regional development and entrepreneurship.[32]

Looking at venture capital investments in the life sciences from 2002 to 2004, California led the way with more than $2 billion invested on average each year; that translated to $142 per $100,000 of gross state product (GSP) in 2004. California was the only state with more than $1 billion invested on average per year in the life sciences. Massachusetts stood at the second place with $873 million invested within the same period.

Appendix A shows the venture capital invested in the life sciences and the number of business start-ups broken down by state. From the table, we can see that Massachusetts has higher life science investments per $100,000 of GSP in 2004. Both Massachusetts and California had 57 and 126 business start-ups in life sciences, respectively, between

2000 and 2004. But California is considerably larger, with 264,557 registered companies compared to 54,104 in Massachusetts (just 20 percent of the California total) as of September 2007, so considering the relative size of these two states puts the numbers into perspective. Although California and Massachusetts are both powerhouses in this field, the latter's industrial base is more skewed towards life sciences than California's.

In terms of biotechnology funding, California ranks as the top state with $2.36 billion, with strong life sciences industries in San Francisco, San Diego, San Jose, Oakland, Los Angeles, and Orange County.[33] This is markedly higher than second- and third-place states Massachusetts and Pennsylvania, with $976.9 million and $351.2 million, respectively.[34] San Jose, California, received more than 15 percent of total biotech venture capital funding in the United States between 2000 and 2003.[35]

The geography of life sciences venture capital is similar to the geography of life sciences innovation. The presence of high-profile research universities in the life sciences clusters of these states has proven to be a powerful economic catalyst. In the United States, university policies require research results to be publishable and owned by the universities. In exchange for their sponsorship, industry players may receive options to license and commercialize these inventions.[36] These partnerships with private industry often provide universities with significant licensing income that allows them to bolster their research programs. Efficient flows of innovation from universities to commercialization have made these states magnets for domestic and foreign venture capital.

Anchoring Life Science Capital in the United States

As we previously noted, in 2004 California had the highest number of life science business start-ups in the nation, with 126 companies. Massachusetts, although ranked second, had less than half California's number of life sciences business start-ups. Incidentally, the following state occupying the third position, North Carolina, had less than one third of California's life science start-ups since 2000. This suggests that new life sciences industry players are relatively anchored in key states like California and Massachusetts.

Business Starts in Life Sciences			
Rank	State	Start-ups, since 2000	Score
1	CA	126	100.00
2	MA	57	83.60
3	NC	39	75.75
4	FL	37	74.66
5	NY	33	72.30
6	NJ	32	71.66
7	TX	31	71.00
8	MN	28	68.90
10	IL	18	59.76
15	MI	13	53.04
17	PA	12	51.38

In 2004, California had the highest number of Technology Fast 500 Companies in the life sciences nationwide. However, standardizing this to the number of businesses, Massachusetts took over the first position at 4.5 companies per 100,000 businesses. The following table illustrates this finding.

Tech Fast 500 Companies in Life Sciences

2004

State	Number, 2004	Per 100,000 Businesses, 2004
California	34	4.1
Massachusetts	8	4.5
Pennsylvania	8	2.7
Texas	6	1.2
Washington	6	3.6
Colorado	5	3.5
Maryland	5	3.8
Minnesota	5	3.5
New Jersey	5	2.1
New York	5	1.0
North Carolina	4	1.9
Connecticut	2	2.2
Georgia	2	1.0
Florida	1	0.2
Idaho	1	2.6
Illinois	1	0.3
Kansas	1	1.3
Michigan	1	0.4
Tennessee	1	0.8
Wisconsin	1	0.7

This shows that California is a life science capital powerhouse by virtue of its industry size, but the industrial base of Massachusetts is more heavily concentrated in the life sciences. Despite its small geographic size, it has a similar number of Technology Fast 500 life sciences firms as larger states such as Pennsylvania and Texas. Nonetheless, these four states take the lead in terms of life science anchors.

The following table shows the venture capital investments in the life sciences in selected states. (While VC represents only a portion of the private-sector funding that drives this sector, it is nonetheless an interesting measure for grasping trends and possible future evolution.) As expected, Massachusetts and California had the highest amount of VC investments in their life sciences industries. Even after normalizing by $100,000 GSP, the two states still lead the nation, with Massachusetts having a clear advantage over California.

Life Sciences VC Investment

Rank	State	Average Annual 2002-2004, US$ Mil.	Per $100,000 GSP, 2004	Score
1	MA	873	292.9	100.0
2	CA	2048	142.3	99.8
3	NJ	299	77.9	85.7
6	NC	208	67.6	82.8
7	MN	167	80.4	82.8
8	PA	201	46.9	80.3
16	TX	103	12.8	68.2
18	NY	72	8.6	63.8
20	MI	36	10.4	61.3
23	IL	38	7.8	59.8
27	FL	33	6.0	57.3

Looking at the companies receiving life sciences VC investments, California and Massachusetts again top the United States. Normalizing the average annual VC investments by 100,000 businesses, California showed up as the state with the highest number of companies receiving VC investments, with Massachusetts a close second.

Companies Receiving Life Sciences VC Investment				
Rank	State	Average Annual 2002-2004, US$ Mil.	Per 100,000 Businesses, 2004	Score
1	CA	192	23.4	100.0
2	MA	69	39.5	97.5
5	PA	28	9.3	78.5
6	MN	18	12.8	78.5
7	NC	19	9.3	76.0
11	NJ	16	6.8	72.1
15	TX	19	3.9	68.2
19	IL	9	3.0	61.1
20	NY	12	2.4	61.1
22	FL	9	2.0	57.5
25	MI	6	2.5	56.2

Taking a closer look, we analyzed the growth in life sciences VC investments. In this regard, California maintained its leading position but Massachusetts fell behind Pennsylvania. This means that California's life sciences industry is still growing, while in Massachusetts, the industry is reaching maturity. At the same time, although Pennsylvania did not have comparable life sciences VC investment amounts, it was growing rapidly, ranking second in the United States in terms of growth.

Life Sciences VC Investment Growth				
Rank	State	Absolute Growth, 2002-2004, US$ Mil.	Relative Growth, 2002-2004, US$ Mil.	Score
1	CA	731	144.9	100.0
2	PA	228	285.1	96.8
3	MA	296	143.4	94.3
6	TX	82	222.9	88.9
9	MI	36	226.4	83.9
10	NJ	48	125.8	82.1
20	IL	-1	96.0	41.7
22	MN	-35	84.5	40.9
25	FL	-15	58.1	38.7
28	NY	-62	46.7	37.3
31	NC	-208	34.7	35.5

The number of California *companies* receiving VC investments, however, did not show high growth. In this measure, California ranked fifth in the United States. This could have been due to California's relative level of maturity in its life sciences industry, which has already built a huge base. Massachusetts ranked further down in this measure at only twenty-second in the nation, with a total loss of seven life science companies receiving VC investments between 2002 and 2004. Nationally, this trend could mean that the life sciences industries are slowly spreading across the nation and may not remain so heavily concentrated within a few key states in the future.

Growth in Companies Receiving Life Sciences VC Investment				
Rank	**State**	**Absolute Growth, 2002-2004**	**Relative Growth, 2002-2004**	**Score**
5	CA	5	333.3	91.7
9	FL	2	133.3	75.0
14	IL	1	109.1	68.3
16	NJ	0	133.3	57.9
22	MA	-7	74.1	41.3
25	MI	-1	66.7	40.7
26	MN	-1	66.7	40.7
30	NC	-2	53.3	39.3
34	NY	1	0.0	27.6
38	PA	-3	0.0	0.0
43	TX	0	0.0	0.0

From the above findings, we can see that California and Massachusetts led the United States in terms of life science VC investments, but in terms of growth in the number of companies receiving those VC investments, these two states did not perform as well. This means that the life science clusters in the old guard (Massachusetts, Pennsylvania, and California) are facing competition from up-and-coming states such as Arizona and Arkansas. VC interest is gravitating towards new life science centers. The industry is developing nationwide, as innovation is spreading across the country and attracting domestic and foreign capital.

4. The Government's Role in Supporting the Innovation Pipeline

At the heart of the knowledge-driven aspect of the life sciences industry is the innovation pipeline. The government has played an instrumental role in promoting innovation in the United States, acting as a key catalyst.

For example, the United States allows scientists and researchers to retain ownership of their federally funded inventions—a strong motivating factor for R&D efforts. In contrast, although Japan is one of the leading countries in life sciences R&D, its innovation system may actually hinder the country's R&D efforts. In Japan, owners have all rights to royalties received from intellectual property rights.[37] But those owners may not be inventors or scientists, potentially subjecting scientists to a bureaucracy that may inhibit their R&D efforts.[38]

Looking at National Science Foundation (NSF) and National Institutes of Health (NIH) funding in the United States, as well as Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards, we can see that California, the leading state in terms of innovation, is given the highest level of support from the U.S. government. It is not surprising therefore, that California possesses the highest level of R&D assets in the country.[39] The following sections provide a description of the life sciences industry by state.

Funding the Growth of R&D Assets

R&D assets drive technological innovation and product creativity in the life sciences industry to a greater degree than in most other arenas. Life sciences and their means of delivery (whether through medical devices or hospital systems) are heavily dependent on basic research. This type of research is conducted by scientists at strong academic research institutions and medical research facilities, supported by public funding or by funding from life sciencies companies.

In Appendix B, we have broken down life science expenditures by state and by industry segment. These expenditures are an indicator of each state's level of R&D funding. The findings show that California, New York, Texas, Pennsylvania, and North Carolina are the leaders in R&D funding—leading in turn to their position as leaders in life sciences industry development.

Rewarding Innovation

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards assist in technology commercialization in a region and are indicators of innovation in a region. The number of awards and amounts rewarded are indicators of the value of R&D in the United States. According to existing research, SBIR-funded start-ups that are affiliated with academic scientists enjoy significantly more follow-up VC funding than those that do not have SBIR linkages.[40]

Appendices C and D show a breakdown of SBIR and STTR awards by state from 2002 to 2004. California and Massachusetts are ranked consistently as the top two states respectively in terms of SBIR and STTR awards. These rankings suggest that innovation is consistently concentrated in these two states.

Financing Life Sciences Research

In the United States, R&D funding from the National Institute of Health (NIH) is a major expression of government support for life sciences research. Part of the U.S. Department of Health and Human Services (HHS), the NIH is the primary agency that conducts medical research and directs major life sciences research.[41] In 2006, the NIH invested almost $21 billion in life science research (only 0.04 percent of which was invested outside the United States).

It does not come as a surprise that California, Massachusetts, New York, Pennsylvania, and Texas are among the top recipients of NIH funding. With the exception of Massachusetts, the other four states are also those with the highest R&D expenditures in the United States.

NIH funding by State, 2006

State	US$Millions
California	$3,142
Massachusetts	$2,204
New York	$1,898
Pennsylvania	$1,391
Texas	$1,075
Maryland	$999
North Carolina	$934
Washignton	$814
Illinois	$696
Ohio	$627

Source: NIH

The performance of these states ties back to their cycles of innovation. In the 1970s, Boston and San Francisco were leaders in research. Today, they are leaders in all aspects of the industry. Other geographic concentrations include Philadelphia and New York, which have developed around pharmaceutical anchors. San Diego and Raleigh-Durham, North Carolina, also have notable clusters. Each of these regions capitalized on their well-funded medical research centers and top universities.[42]

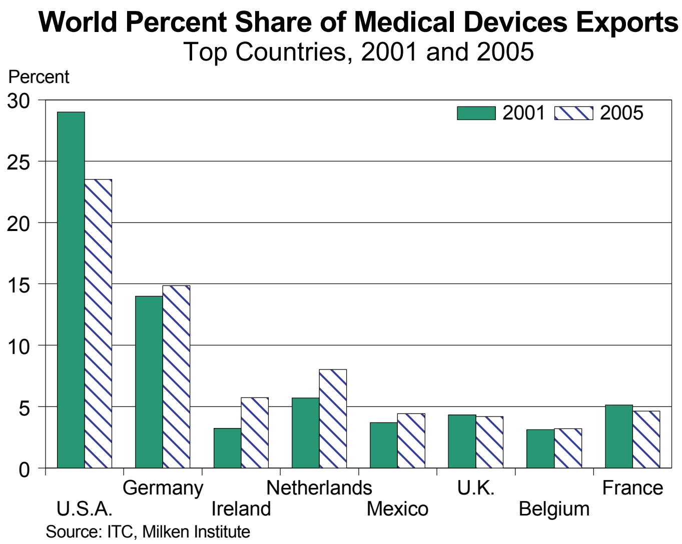
5. A Global Leader: International Competitiveness

With an estimated $77 billion in production in 2002, the United States leads the world in terms of medical technology production.[43] According to the Lewin Group, the industry shipped products worth a total of $123 billion in 2006.[44] In the same year, the total R&D expenditure in pharmaceuticals ($37 billion), biotechnology ($18.2 billion), and medical devices ($9.5 billion) totaled almost $65 billion.[45]

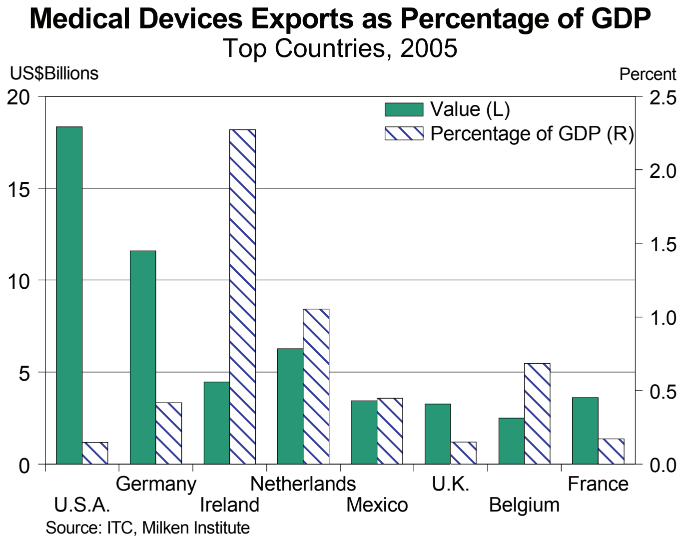
Medical Devices: World Share of Activities

Exports can be seen as an indicator of international competitiveness. A country that has significant exports of a product is one that is a leading contributor to the world's supply of that product, making that nation a competitive producer in a particular industry.

Not surprisingly, the United States leads the world in medical-device exports. Having the most competitive life sciences industry in the world, the United States accounted for almost 30 percent of the world's supply of medical devices in 2001; the closest competitor, Germany, followed with less than 15 percent. However, as shown in the following table, U.S. competitiveness in medical devices weakened in 2005, with its share of world exports dropping to less than 25 percent. In contrast, Germany's exports share increased slightly, while Ireland, the Netherlands, and Mexico gained ground in 2005.



These findings mean that while the United States continues to be a competitive leader in medical devices, its percent share is falling as European nations catch up. As shown in the following chart, Ireland's medical devices exports made up almost 2.5 percent of its GDP. In contrast, U.S. medical devices exports constituted less than 0.5 percent of its GDP. Therefore, it can be inferred that the German, Irish, and Dutch economies, for example, are more heavily dependent on medical devices than the U.S. economy.



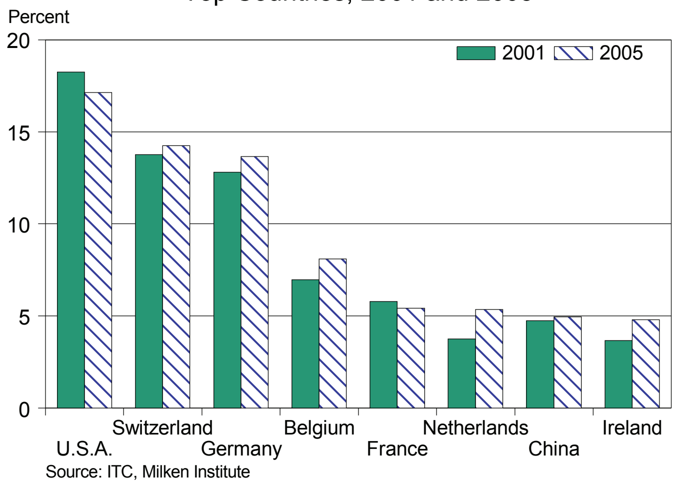
Pharmaceuticals: World Share of Activities

The same pattern holds true for pharmaceuticals, an important component of the life sciences industry. In 2004, it stood among the most research-intensive sectors of the U.S. economy, with $30.6 billion invested in R&D. [46] In 2007, biotechnology and pharmaceutical companies invested $55.8 billion in research and development.[47] Indeed, the pharmaceuticals industry is a critical knowledge-intensive sector of the U.S. economy, and subsequent trends show that level of investment continuing to grow. Biopharmaceutical firms, which combine pharmaceuticals and biotechnology, invest a high 10 to 20 percent of their sales back into research and development. [48] Despite constituting only 0.3 percent of the total non-farm employment, biopharmaceuticals accounted for 8.2 percent of U.S. industrial R&D in 2002.[49]

Again, in terms of the international market, the United States was a leader, producing about 18 percent of the world's total pharmaceutical exports in 2001. Next in line were Switzerland and Germany at about 14 percent and 13 percent, respectively.

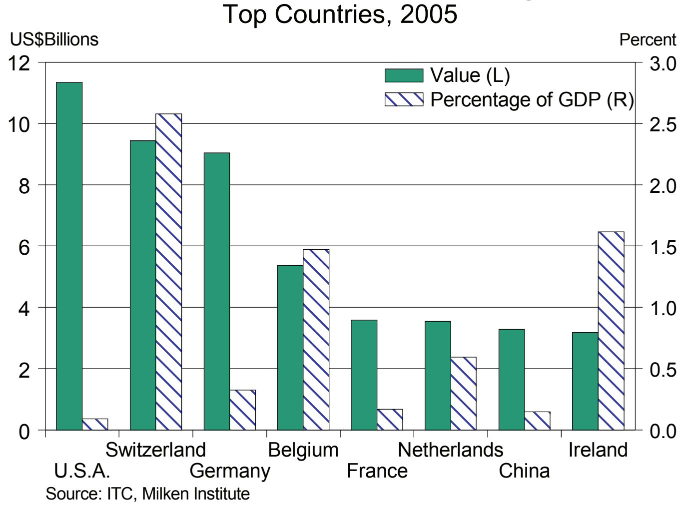
As shown in the following chart, the United States remained a leading exporter of pharmaceuticals in 2005, but its share of the world export market dropped slightly, to about 17 percent. In contrast, Switzerland and Germany increased their respective shares somewhat, but still failed to capture 15 percent.

World Percent Share of Pharmaceuticals Exports
Top Countries, 2001 and 2005



Similar to the case of medical devices, pharmaceutical exports did not account for a large percentage of U.S. GDP in 2005. Though the United States produced more than $11 billion of exports, that figure adds up to less than 0.2 percent of GDP. In contrast, pharmaceutical exports from Switzerland, which were just under US$10 billion, constituted more than 2.5 percent of the country's GDP in the same year.

Pharmaceuticals Exports as Percentage of GDP
Top Countries, 2005



The pharmaceutical and medical manufacturing industry employs a high number of scientists and engineers, making it unique among U.S. manufacturing sectors. In 1999, this industry employed 133 scientists and engineers per 1,000 workers. This is similar to various computer- and electronics-manufacturing industries such as navigational, measuring, electro-medical, and control instruments (133 scientists and engineers per

1,000 workers) and semiconductors and electronic components (141 scientists and engineers per 1,000 workers). Of note, the highest employment of scientists and engineers occurred in communications-equipment manufacturing (313 scientists and engineers per 1,000 workers) in the same year.[50]

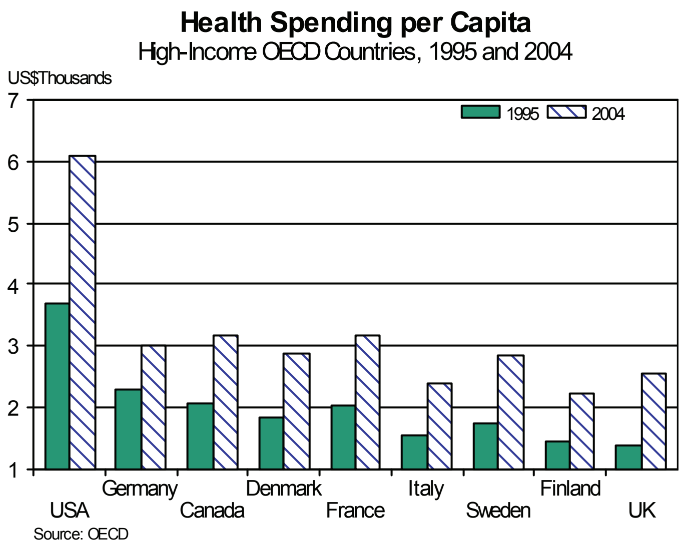
By 2003, the pharmaceuticals and medicine manufacturing industry saw its employment concentration of scientists and engineers increase by 15.3 percent from the previous year to 158 per 1,000 workers. Manufacturers of communications equipment and semiconductors and other components saw a 24.5 percent decrease and 11.7 percent increase respectively from 2002. Although these two industries employed more scientists and researchers per 1,000 workers in 2003 (290 and 201), pharmaceuticals and medicines manufacturing remain a key industry that increasingly capitalizes on R&D, given the increasing number of knowledge workers in its employment base.[51]

6. The Delivery Component: Health-Care Services

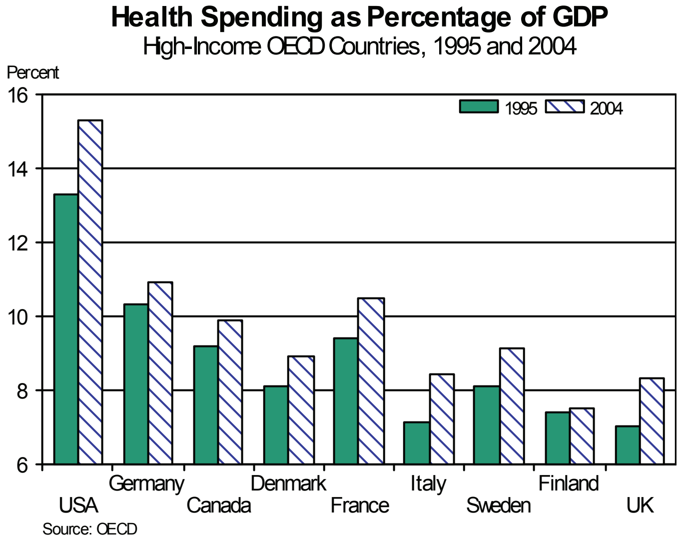
The main delivery component of the life sciences industry is the health-care system. This is where a region can utilize its innovation capacity and industry for practical applications of its R&D and commercialization ideas. It is a task with many challenges Life science firms bringing new discoveries to the market face many hurdles and costs in the discovery and approval process, in tough financial market conditions, in sales and marketing expenditures, and in legal constraints. Meanwhile, the focus on health-care expenditures requires the delivery of better care and clear cost benefits to be sustainable in the long term.[52]

This section will illustrate an opportunity for the United States to take advantage of its considerable life science assets to address the demands on its health-care delivery system: Beyond exporting its life sciences innovation, the strong U.S. life sciences innovation pipeline can provide the needed mechanisms to continuously produce and deliver revolutionary health-care services to its own local markets and beyond. A close collaboration between centers of both research and health care (such as university medical centers) and the core life sciences R&D industries can further enhance the global leadership position currently enjoyed by the United States.

Based on statistics from the Organisation for Economic Cooperation and Development (OECD), the United States has the most expensive health-care system in the world.[53] The following two charts summarize health spending per capita among high-income OECD countries in 1995 and 2004. For all countries, health spending increased over this period. In both years, the United States faced the highest costs, with more than $4,000 and $6,000 spent per capita, respectively. Canada and France have high spending relative to other countries but did not come close to U.S. levels. As shown in the following chart, all other countries came in at less than half of U.S. spending



Comparing health spending as a percentage of GDP, the United States again posted the highest spending at almost 14 percent in 1998. This further increased to almost 16 percent of GDP in 2004. In 1998, Switzerland and Germany exceeded 10 percent of their GDP in health spending. In 2004, there was an increase in health spending across the eight countries, with France exceeding the 10 percent mark in the same measure. Nonetheless, the United States far outspent all other countries in both years. This is due to greater chronic disease prevalence, higher treatment rates, more widespread deployment of the latest innovations in medical research, and the administrative costs of insurance companies.



In general, health-care costs are higher in the United States than in European countries. According to a recent study by Thorpe, Howard, and Galactionova, per capita health-care spending in the United States was $6,037 in 2004. In the same year, the highest per capita health-care spending in Europe occurred in Switzerland at only US$4,045, about two-thirds of U.S. levels.[54] As shown in the following table, several developed European countries such as France and Italy spent less than $4,000 per capita on health care in 2004.

Total per Capita Health Spending

US$, PPP, 2004

Country	Total per Capita Health Spending (US$, PPP)
U.S.	$6,037
Switzerland	$4,045
Austria	$3,418
France	$3,191
Germany	$3,169
Netherlands	$3,094
Denmark	$2,972
Sweden	$2,827
Greece	$2,669
Italy	$2,437
Spain	$2,099

Source: OECD, 2007

Much of the higher cost can be explained by the higher prevalence of chronic disease in the United States—and second, by the tendency of the U.S. health-care system to respond aggressively in extending treatments to patients with those chronic diseases. Take heart disease, for example: 60.7 percent of U.S. patients diagnosed with the disease were receiving medical treatment, compared to 54.5 percent in Europe.[55] The following table compares the treatment prevalence between the United States and Europe. In examining nine chronic diseases, a greater percentage of patients in the United States received treatment.

Comparison of Treatment Prevalence by Disease

U.S. and Europe, 2004

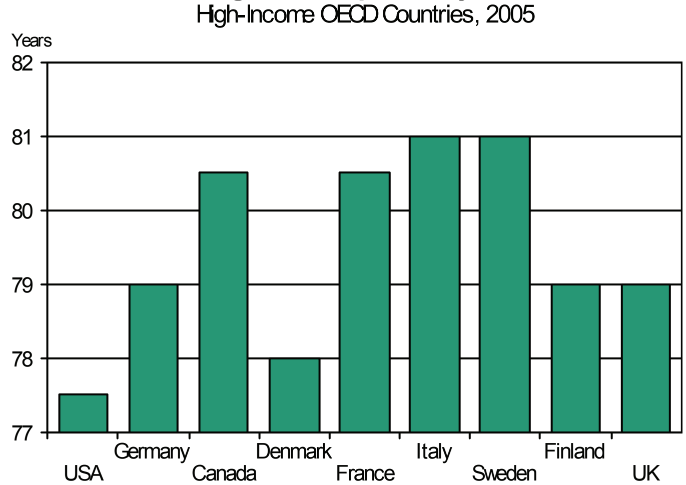
Disease	U.S. (%)	Europe (%)
Heart Disease	13.2	6.2
High Blood Pressure	44	29.3
High Cholesterol	19.1	12.3
Stroke/Cerebrovascular Disease	2.4	1.6
Diabetes	13.3	8.9
Chronic Lung Disease	5	1.5
Asthma	3.7	2.8
Arthritis	24.1	10.6
Osteoporosis	4.1	3.4

Source: Thorpe, Howard, Galactionova (2007)

From the following chart, we can see that the average life expectancy at birth for U.S residents in 2005 ranked the lowest among eight high-income countries, at 77.5 years. This means that while the United States spends more per capita on health-care services, the nation's life expectancy remains lower than that of other countries that spend less on health care.

Average Life Expectancy At Birth

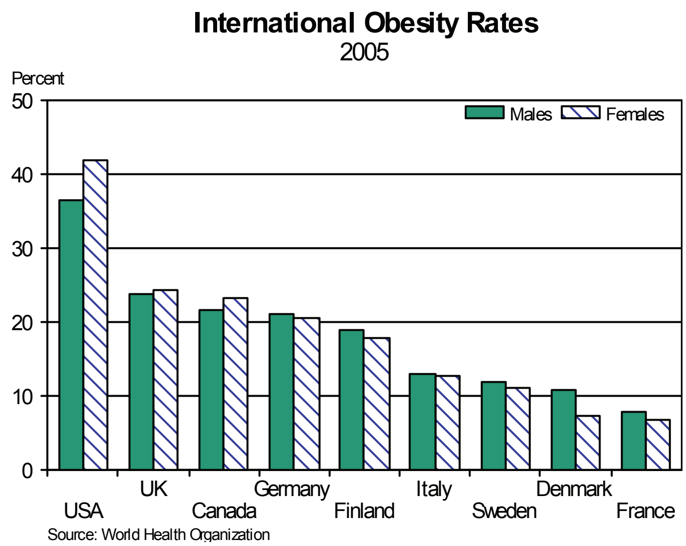
High-Income OECD Countries, 2005



Source: OECD

The key to the puzzle is that life expectancy is at least as much a function of lifestyle as of health-care treatment. Obesity can be argued to be a result of lifestyle habits, such as an individual's food choices and frequency of exercise. More important, according to research published in the *Journal of the American Medical Association,* severe obesity (defined as a body mass index, or BMI, above 45) can lead to a loss of four to twenty years of life expectancy.[56] America's obesity epidemic is clearly straining its health-care system and raising treatment costs.

The following chart illustrates the obesity (BMI greater than or equal to 30) rates among several developed countries as of 2005. Clearly, the United States leads in obesity prevalence, with about 36 percent of males and 42 percent of females in its population classified as obese. This stands in sharp contrast to neighboring Canada, where obesity prevalence for both males and females was less than 25 percent. France scored the lowest in this measure, with less than 10 percent of its population deemed obese.



By all of these measures, the U.S. population is not as healthy as citizens of other developed countries. The nation's obesity epidemic far outstrips the extent of the problem in other nations; the second-highest prevalence rate, seen in the U.K., was less than two-thirds of U.S. levels.

Obesity translates to a higher incidence of chronic diseases, which call for extensive and prolonged treatment. Hospitals and medical centers are treating a myriad of complex conditions that can be traced to obesity, and the costs are staggering. It is clear that health-care costs are tied closely to the basic lifestyle and fitness level of the population.

The higher prevalence of disease in the United States has led directly to the country's lower life expectancy. This adds another dimension to the life sciences. Effective delivery of medical innovations through the life science industry is critical because of the translated opportunities.

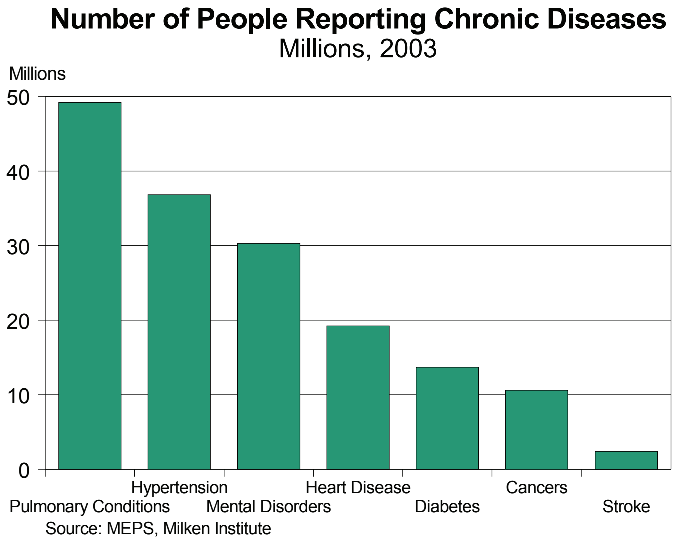
The high cost of health care in the United States is undoubtedly a burden. Companies are spending ever-larger sums on health insurance and employee benefits, while individuals are also feeling the pinch of rising costs. Given that Americans are less healthy than their European counterparts, it does not seem likely that health-care spending will be reduced, despite increased investments in life sciences and health care.

However, this burden can be transformed into an opportunity. The United States is a leader in life science innovation, with strong investment support from the government and the private sector. Cutting-edge life science clusters are flourishing around the country, well beyond historically dominant centers like Boston. These are avenues for innovation and investments to reap further benefits for the industry and the U.S. economy as a whole. Putting new focus on delivering these innovations to a wider population can be a key to reductions in overall health spending, according to Thorpe, Howard, and Galactionova.[57]

A smart and effective approach to delivering innovations and preventive care could lead to a healthier population—unlocking higher productivity and economic growth. The prevalence of chronic diseases has created a huge drag on the U.S. economy, as the next section will show. Reducing these conditions will lessen this burden and enhance growth. This opportunity is uniquely applicable to the United States, which has stronger life science R&D assets and a more vibrant industry base to leverage than other countries.

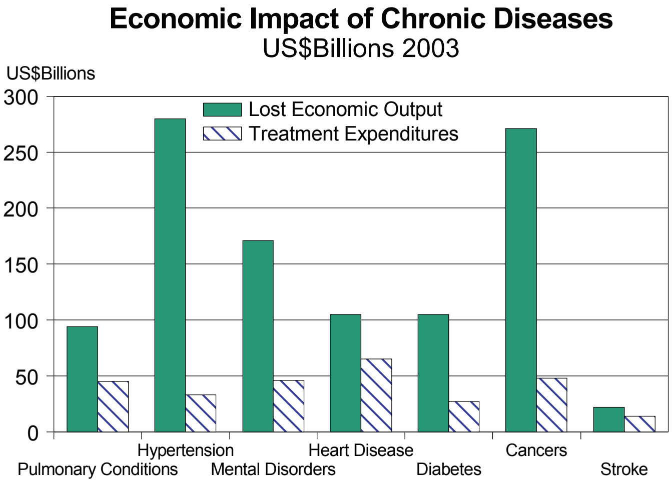
7. A Unique Opportunity for the United States

More than 50 percent of the U.S. population suffers from at least one chronic disease.[58] The increasing prevalence of chronic disease is a critical factor driving up medical costs.[59] In this section, we will take a look at the health-care burden posed by seven conditions: pulmonary ailments, hypertension, mental disorders, heart disease, diabetes, cancers, and stroke. The following figure depicts the number of people in the United States who reported these chronic conditions in 2003.



According to findings from a recent Milken Institute study, even modest improvements in prevention and treatment (i.e., health-care service delivery) have the potential to head off 40 million cases of chronic disease by 2023. In addition, the economic impact of chronic disease can be reduced by 27 percent ($1.1 trillion) annually. The United States can enjoy productivity gains that will increase GDP by $905 billion, while treatment costs can be reduced by $218 billion annually. Lower obesity rates *alone* can facilitate a gain of $254 billion in productivity and a reduction of $60 billion in treatment costs per year.[60]

The following figure summarizes the economic impact of this issue. Based on these seven conditions alone, the total burden of chronic diseases (treatment expenditures and lost economic output combined) amounted to $1.3 trillion in 2003. Hypertension and cancer accounted for the highest economic impact, at $280 million and $271 million, respectively. The treatment costs for these diseases were substantially lower than the lost economic output. These costs do not include costs of follow-up treatments for the associated health consequences (co-morbidities) of these diseases.



Source: MEPS, NHIS, Milken Institute
Expenditures incurred in nursing homes, prisons, or under other institutional care, comorbidities and secondary effects of diseases are excluded.

Fast-forward to 2023. Assuming current trends persist, the Milken Institute envisions a 42 percent increase in the incidence of these seven chronic diseases, creating a total of 230.7 million cases. In addition to the toll in human suffering, the United States will incur $4.2 trillion in treatment costs and lost economic output.[61]

Exploiting the Opportunity

Given the obstacles faced by the U.S. economy as a result of its high prevalence of chronic diseases, it is imperative to reduce these rates if we hope to increase productivity. With its uniquely strong R&D assets and its visionary life science industries, the United States can develop policy frameworks and incentives to better extend medical innovations to the entire population.

This will not only reduce the prevalence of chronic diseases, but also complete the virtuous cycle of life science innovation-industry-delivery, whereby R&D assets are commercialized and delivered to consumers, thus resulting in further innovation and investments.

Given that the United States is a leader in life science R&D, our nation is certainly capable of providing better health care to its population. This can be done effectively because of proven technology-transfer linkages and efficient innovation policy frameworks for commercializing life science innovation. With strong public and private capital support for the U.S. life science industry, the high demand for medical treatment can serve as a boost to facilitate further R&D for commercialization.

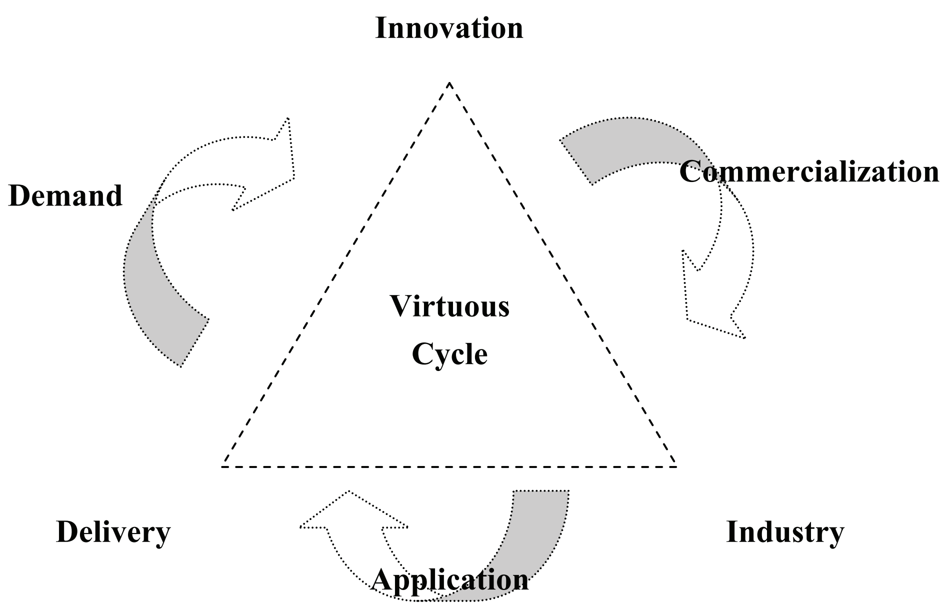
For businesses outside the life sciences, the main benefits will accrue from utilizing medical advances to improve health care for employees through improved detection and better understanding of the risk factors that lead to the diseases. Although preventive care is fairly straightforward, actual implementation by corporations among their employees is low.

At the same time, the model of research and development that has led to such a large concentration of the world's life science research in the United States is one from which non-life science corporations can also draw inspiration. Universities, industry, and health-care facilities are closely linked in this virtuous cycle. The concentration of research in medical devices, pharmaceuticals, and treatment has allowed for the development of effective medical research centers that not only attract government research money, but have also proven able to effectively partner with businesses and health-care providers.

A prime example of this cooperation can be found in Philadelphia, where life sciences research facilities at universities such as Drexel and the University of Pennsylvania combine with the presence of leading pharmaceutical companies in the city and in nearby New Jersey to create opportunities for actual applied research that can benefit both patients and businesses. Pennsylvania Hospital, the first hospital in the nation, is a part of the University of Pennsylvania, an Ivy League university established in 1751. The university gave rise the first medical school and teaching hospital in the United States, and it continues that tradition of innovation into the present day, serving as a model for R&D.[62]

Today, the university receives funding support from the NIH to support its R&D efforts. In 2006, the university received more than $452 million, topping the list of awardees in Pennsylvania. Second place went to the University of Pittsburgh at about $377 million.[63] With these R&D assets as possible key attractions, foreign direct investment in the Philadelphia region placed the state in one of the top positions in life sciences industry (as shown earlier). Numerous key pharmaceutical firms such as GlaxoSmithKline are invested heavily in the region. One company in the Philadelphia region that is not considered to be a traditional life science business--but clearly benefits from this relationship—is the chemical giant DuPont. DuPont is one of the region's largest employers, promoting basic research in areas such as agricultural biology and biotechnology. [64] DuPont has been able to utilize the resources of life sciences research in the Philadelphia region to develop new products that are not considered to be part of the traditional life sciences.

The case of Philadelphia illustrates the intersection of innovation, industry, and delivery in furthering U.S. leadership in the life sciences industry. With expanding and new emerging industry clusters, a strong innovation pipeline, and high demand for health-care services, there is a clear opportunity for businesses to capitalize on an advocacy relationship with universities and the government in an effort to trigger further groundbreaking R&D. Further research could ascertain the value added by computing the impact of life science investments on the U.S. economy and how it feeds its innovation system.



8. Key Points

Overall, the United States has proven itself to be a leader in terms of medical breakthroughs and developing sophisticated health-care treatments. It is a magnet for public and private funding and capital due to the high levels of innovation, with strong and competitive life science industries.

However, there are inherent challenges in health-care delivery. Great obstacles must be overcome if we hope to improve the overall health of all Americans. But the challenges represent a unique opportunity—an opportunity that the United States is well-positioned to meet by deploying its strong R&D assets, its efficient innovation pipeline, and robust industry base. By addressing these issues directly, through a strong collaboration of industry, R&D institutions, and the government, we have the potential to increase overall productivity and boost economic growth.

The health of employees can bring direct benefits to their employers; a healthy work force is vital to our economy. By teaming up with health-care providers to offer preventive services such as wellness initiatives, companies can lower their medical and insurance costs.

Research has shown that company investments in such work-based health programs have realized substantial returns on their investments: for every dollar spent on prevention, they typically see $3.48 from reduced health-care costs and $5.82 from lower absenteeism costs.[65] According to a study by the National Business Group for Health (NBGH), companies that have invested in worker wellness programs for five years can enjoy returns of at least $3 and $8 per dollar invested.[66]

Dell Inc. employs about 16,000 workers in the Austin area. The company has introduced an employee wellness program that includes many athletic programs, including fitness center services. Along the same lines, Cleveland-based Progressive Corp. offers free health risk appraisals to employees, and a program called "10k a Day." Under this initiative, pedometers are distributed to employees, who are encouraged to walk at least 10,000 steps a day. Prizes are offered as a motivation.[67]

These examples and statistics show that companies can take creative preventive measures to reduce medical costs. These investments have direct and indirect benefits to the companies and economy respectively.

Leading Life Sciences Innovation and Industry

As shown earlier, the United States leads the world in terms of medical technology production.[68] With strong R&D investments and exports, it maintains its position as a leader in medical innovation. However, it is also important to note that the United States has clear competition. Medical-technology production may be moved overseas to India, for instance, in order to lower production costs. Siemens, a leading German firm, enjoyed impressive sales of $12 billion in 2006.[69] The United States must therefore exploit its existing assets to maintain its global competitive edge.

As key sources of life sciences innovation in the last three decades, universities are striving to reprise their influential role in knowledge development, extending life sciences research agenda to new areas. Advances in biotechnology and nanotechnology have helped to drive the industry forward. Newer treatments and examination procedures have been developed for various forms of cancer and other chronic diseases based upon the partnership between research centers and business. The private sector facilitates this process by supporting the commercialization of these discoveries under the regulatory procedures. When considered together, the U.S. private and public sectors constitute a powerful innovation pipeline.[70]

Biotechnology is a vital component in the life sciences industry mix. In this realm, the United States leads the world as a result of direct and indirect government promotion of innovation.[71] The U.S. university system enjoys well-linked collaborations with public and private institutions based on joint goals of understanding and use. This characteristic has always been a significant factor contributing to technological development and industrial performance.[72] Indeed, the Bayh–Dole Act facilitated the transfer of university innovation to the market, thus enabling commercialization while simultaneously extending university property rights to federally funded inventions.[73]

An Opportunity for the U.S. Health-Care System

Citing findings from a groundbreaking study conducted by the World Health Organization (WHO), the United States has the most expensive health system in the world.[74] This has been attributed to factors such as the increasing costs of medical technologies, medicine, and administration (the multi-payer health system in the United States funnels approximately 19 to 24 percent of health-care spending toward administrative costs). But perhaps the most significant factor to consider is the growing prevalence of chronic disease.

Although the United States has a high treatment rate for chronic diseases, much of the population still lacks access to these high-quality medical services. The United States is the only developed country in the world besides South Africa that does not provide universal health-care services. In 1999, 42.6 million people in the United States were uninsured.[75] In 2003, about 35 percent of adults under age 65 (61 million people) were not insured or were under-insured at some point during the year. Some 34 percent of all adults under age 65 had difficulties affording their medical loans or bills. Less than half of adults (49 percent) received preventive and screening tests in accordance to age and gender guidelines. Also, about half of congestive heart failure patients received written discharge instructions in regards to post-hospitalization care. Insurance premiums are rising much faster than median household incomes, making it even harder for many Americans to afford health-care coverage, despite the quality of care that might be available.[76]

One area in which businesses can be proactive in working with life science firms and health-care providers is in taking steps to prevent or mitigate disabling diseases or conditions among workers. Partly due to the low emphasis currently placed on preventive care, according to the WHO report in 2000, the United States ranked twenty-fourth in the world in disability-adjusted life years. This low ranking, especially when compared to other high-income OECD countries, translates into many years of life being marred by disability..[77] These disabilities not only affect quality of life, but also impact the capacity of patients to stay productive in the workforce. It is a vicious cycle that increases costs for patients, employers, and health-care companies alike.

It is both a challenge and an opportunity for the U.S. health-care system to find a way to extend high-quality services to a greater number of patients. We have shown the economic burden caused by an unhealthy population—and that in turn suggests a great economic benefit that can be obtained by implementing effective prevention and delivery of health care. In order to develop an effective strategy for battling rising health-care costs, engaging in effective wellness programs and providing incentives to workers for reducing risky behavior such as smoking and obesity could go farther to reduce costs than most other factors. Companies can also cooperate with pharmaceutical companies, medical-device firms, and health-care providers on clinical trials to allow their employees inexpensive and early access to new treatments and preventive techniques.

Conclusion

The United States has a strong foundation in life sciences R&D. Its high levels of public funding and private capital, as well as its tradition of innovation, make it a leader in the knowledge-intensive production aspects in the life sciences (in particular, the therapeutics and devices component). Life science is one of the key growing sectors of the knowledge-based economy, and the United States maintains a competitive advantage over other countries. But the nation will need to exploit these strengths and try new approaches to reduce the growth of expenditures and improve economic performance.

The poor overall health of Americans translates into tangible economic losses. Findings from the Milken Institute study on the economic burden of chronic diseases suggest that improvements in prevention and treatment can facilitate a major reduction of chronic disease occurrences by 2023, thus reducing their economic impact substantially. Although there are other factors driving the rapid rise in health-care costs, U.S. businesses do have it within their power to take steps to reduce risk factors among employees. Along with the incalculable human benefits, the United States can experience increased productivity and lower treatment costs. By establishing creative partnerships with the life sciences industry to focus on improved service delivery and targeted preventive care, we can improve the health of Americans and reduce the economic burden of chronic diseases.

Harnessing the nation's strong R&D assets and the impressive ingenuity and intellectual capital of the life sciences industry will be the key to setting that process in motion. A healthy America with a high-quality health-care delivery system will enjoy a strengthened position as a global leader in life sciences—along with increased productivity and continued economic growth.

The life sciences sector is one of the most dynamic and value-added sectors of the American economy. The United States has built and maintained an impressive lead in research and development over other developed nations. Businesses in other key sectors of the American economy have a tremendous amount to gain by learning from and collaborating with partners in the life sciences.

Appendix A

Venture Capital Investments and Start-ups in Life Sciences by State, 2002 to 2004

State	Average Annual 2002-2004, US$ Thousands	Per $100,000 GSP, 2004	Business Startups since 2000
AK	$0	$0.00	1
AL	$21,633	$17.05	5
AR	$2,089	$2.87	N/A
AZ	$21,111	$11.27	15
CA	$2,047,667	$142.32	126
CO	$95,000	$51.30	14
CT	$93,067	$54.00	15
DC	$25	$37.39	5
DE	$222	$0.45	N/A
FL	$32,644	$6.00	37
GA	$119,478	$38.01	8
HI	$1,311	$2.89	1
IA	$889	$0.86	5
ID	$0	$0.00	N/A
IL	$37,911	$7.81	18
IN	$18,444	$8.85	9
KS	$7,333	$8.16	6
KY	$17,789	$14.34	5
LA	$0	$0.00	2
MA	$872,789	$292.86	57
MD	$172,378	$83.53	19
ME	$7,256	$18.35	2
MI	$35,900	$10.38	13
MN	$166,967	$80.35	28
MO	$60,489	$32.55	7
MS	$222	$0.32	3
MT	$0	$0.00	1
NC	$207,789	$67.55	39
ND	$0	$0.00	1
NE	$0	$0.00	4
NH	$24,711	$50.90	3
NJ	$299,078	$77.94	32
NM	$3,089	$5.48	1
NV	$2,667	$2.95	4
NY	$72,456	$8.59	33
OH	$33,878	$8.82	16
OK	$16,722	$17.30	6
OR	$3,667	$3.02	4
PA	$200,800	$46.94	12
RI	$25,944	$68.24	4
SC	$0	$0.00	2
SD	$0	$0.00	2
TN	$60,833	$30.49	9
TX	$102,544	$12.76	31
UT	$19,311	$25.71	11
VA	$5,522	$1.84	9
VT	$0	$0.00	N/A
WA	$188,578	$79.14	13
WI	$22,167	$11.42	9
WV	$0	$0.00	N/A
WY	$0	$0.00	N/A

Appendix B

Breakdown of Life Sciences Expenditures by State, 2006

	Bioengineering/ Biomedical Engineering	Agricultural Sciences	Biological Sciences	Medical Sciences	Other Life Sciences	Total
AL	$1,607	$62,154	$105,853	$242,668	$9,431	$421,713
AK	$329	$12,846	$17,021	$200	$0	$30,396
AZ	$6,939	$73,761	$140,193	$117,506	$7,774	$346,173
AR	$421	$57,477	$41,075	$54,576	$4,073	$157,622
CA	$48,951	$225,773	$939,301	$2,609,403	$18,080	$3,841,508
CO	$393	$30,033	$88,901	$261,843	$9,025	$390,195
CT	$1,336	$11,268	$194,211	$327,725	$4,289	$538,829
DE	$1,423	$19,085	$8,007	$0	$3,576	$32,091
DC	$235	$1,323	$56,530	$124,618	$6,750	$189,456
FL	$17,479	$143,744	$175,839	$436,206	$22,099	$795,367
GA	$21,673	$94,445	$244,365	$290,367	$62,774	$713,624
GU	$0	$3,569	$247	$861	$531	$5,208
HI	$0	$17,559	$8,677	$46,574	$19,620	$92,430
ID	$73	$34,088	$17,575	$9,097	$59	$60,892
IL	$20,140	$66,882	$367,087	$565,842	$43,974	$1,063,925
IN	$7,603	$94,092	$134,787	$150,479	$14,055	$401,016
IA	$759	$55,428	$100,395	$183,351	$35,519	$375,452
KS	$441	$51,482	$105,893	$36,181	$24,141	$218,138
KY	$5,154	$54,458	$83,085	$172,677	$17,342	$332,716
LA	$4,633	$64,920	$146,058	$113,728	$68,331	$397,670
ME	$254	$11,359	$17,190	$36	$1,543	$30,382
MD	$20,369	$45,884	$275,204	$785,772	$72,430	$1,199,659
MA	$58,659	$18,484	$429,685	$527,818	$63,466	$1,098,112
MI	$15,538	$96,136	$264,913	$414,278	$112,719	$903,584
MN	$2,346	$65,464	$72,979	$257,338	$11,867	$409,994
MS	$230	$89,900	$27,385	$55,232	$14,573	$187,320
MO	$4,209	$70,702	$262,076	$378,680	$13,190	$728,857
MT	$2,898	$58,383	$33,813	$14,257	$2,167	$111,518
NE	$2,384	$56,451	$112,214	$64,000	$25,858	$260,907
NV	$0	$16,443	$33,640	$9,547	$1,352	$60,982
NH	$0	$11,920	$19,399	$123,076	$2,004	$156,399
NJ	$5,716	$41,367	$200,232	$180,765	$17,062	$445,142
NM	$0	$22,696	$58,390	$41,001	$16,603	$138,690
NY	$26,083	$85,890	$1,001,369	$1,218,781	$86,199	$2,418,322
NC	$17,418	$75,451	$338,715	$781,074	$41,580	$1,254,238
ND	$0	$46,551	$5,241	$17,402	$2,556	$71,750
OH	$18,786	$47,062	$314,736	$532,055	$46,273	$958,912
OK	$117	$38,186	$61,384	$57,008	$6,733	$163,428
OR	$5,587	$55,320	$162,908	$133,547	$12,476	$369,838
PA	$31,397	$72,815	$348,189	$939,980	$40,738	$1,433,119
PR	$5	$416	$7,323	$53,033	$320	$61,097
RI	$413	$7,091	$27,978	$25,101	$30,204	$90,787
SC	$5,002	$29,786	$84,262	$101,649	$53,309	$274,008
SD	$0	$17,125	$6,314	$15,989	$5,058	$44,486
TN	$9,882	$41,022	$216,885	$198,860	$15,054	$481,703
TX	$24,093	$112,612	$832,273	$1,027,229	$71,405	$2,067,612
UT	$3,330	$30,924	$56,237	$104,258	$25,966	$220,715
VT	$0	$7,805	$36,301	$48,341	$10,245	$102,692
VI	$0	$0	$0	$0	$7,498	$7,498
VA	$6,258	$72,769	$171,475	$212,269	$17,490	$480,261
WA	$14,165	$59,645	$136,370	$387,750	$14,572	$612,502
WV	$8	$19,852	$17,523	$48,209	$3,540	$89,132
WI	$5,094	$44,953	$223,445	$369,271	$8,478	$651,241
WY	$0	$12,518	$14,553	$6,749	$65	$33,885
US	$419,830	$2,657,369	$8,845,701	$14,874,257	$1,226,036	$28,023,193

Appendix C

Breakdown of Small Business Innovation Research (SBIR) Awards by State, 2002 to 2004

	Number of Awards			Award Dollars		
State	2002	2003	2004	2002	2003	2004
CA	1197	1225	1328	$299,262,647	$385,672,622	$415,698,563
MA	799	830	840	$215,459,825	$242,349,779	$277,575,983
VA	333	364	358	$89,717,760	$96,533,591	$111,459,615
CO	294	291	312	$74,253,206	$80,935,801	$88,903,493
MD	274	325	347	$74,284,167	$96,583,463	$113,599,253
NY	224	239	251	$62,654,013	$78,727,244	$99,760,156
TX	220	276	293	$53,422,476	$69,707,720	$89,646,772
OH	220	237	239	$63,526,667	$74,456,522	$71,230,736
PA	205	225	239	$54,884,835	$73,032,625	$71,769,199
NJ	170	181	175	$46,609,103	$41,139,747	$60,477,187
WA	135	132	164	$43,235,991	$40,809,028	$58,890,717
FL	132	150	153	$29,439,666	$41,488,773	$42,228,732
AZ	112	105	109	$34,006,247	$24,528,586	$27,463,629
MI	110	128	122	$23,985,170	$42,059,369	$35,082,016
CT	104	103	93	$23,407,169	$29,600,832	$34,631,585
AL	99	116	129	$29,715,456	$32,861,049	$36,756,135
NM	89	88	92	$19,582,244	$20,183,054	$25,024,547
MN	87	94	70	$26,766,769	$27,402,199	$22,080,760
IL	77	90	94	$16,667,729	$26,033,392	$27,088,702
NH	73	73	70	$19,408,807	$20,430,006	$26,965,004
OR	68	65	71	$18,563,474	$17,027,609	$23,076,338
NC	61	81	108	$23,142,744	$22,157,587	$26,549,242
GA	61	66	65	$14,203,604	$16,325,891	$20,852,375
UT	61	52	49	$15,697,327	$17,186,309	$10,663,761
WI	54	61	59	$15,120,942	$21,950,051	$20,182,744
TN	41	35	32	$10,276,851	$8,383,304	$10,294,063
IN	38	41	35	$8,552,037	$10,928,615	$12,587,835
MT	34	28	33	$6,868,462	$6,617,176	$8,149,180
MO	29	29	37	$6,944,074	$4,314,917	$10,867,734
DC	26	17	13	$7,463,649	$5,185,107	$4,872,564
SC	25	32	16	$6,632,368	$8,508,098	$6,309,600
NV	25	23	22	$7,265,776	$5,683,545	$10,159,621
OK	23	22	42	$5,022,796	$4,539,159	$11,658,389
HI	20	18	19	$3,451,357	$4,356,753	$14,700,800
RI	19	25	21	$5,428,036	$7,612,161	$10,309,695
KS	19	21	21	$5,110,415	$4,289,965	$5,313,502
ME	18	25	29	$2,658,734	$4,444,927	$9,607,963
IA	17	19	14	$5,416,612	$5,206,899	$3,502,502
DE	16	26	24	$2,684,738	$4,234,603	$9,977,547
ID	15	14	16	$4,321,351	$3,021,847	$3,649,666
KY	14	10	16	$4,383,432	$1,688,737	$7,297,532
WV	13	25	22	$1,271,071	$7,852,036	$8,035,011
LA	13	14	21	$3,240,900	$2,373,062	$3,762,972
MS	12	12	15	$3,211,155	$2,343,040	$4,060,724
VT	10	20	17	$2,325,148	$6,833,943	$5,958,998
NE	10	11	9	$1,874,279	$1,246,217	$5,873,218
SD	9	8	1	$2,161,072	$2,098,695	$112,485
AR	8	17	21	$2,034,476	$2,660,862	$5,554,760
ND	7	8	8	$1,361,214	$1,951,437	$1,767,016
AK	2	7	1	$79,243	$1,334,793	$70,000
PR	1	2	2	$96,780	$150,000	$300,000
US	5723	6106	6348	$1,497,154,064	$1,757,042,747	$2,014,585,907

Appendix D

Breakdown of Small Business Technology Transfer (STTR) Awards by State, 2002 to 2004

	Number of Awards			Total Award Dollars		
State	**2002**	**2003**	**2004**	**2002**	**2003**	**2004**
CA	76	69	135	$12,342,460	$13,493,008	$37,326,059
MA	42	60	112	$10,135,433	$13,371,294	$28,105,970
VA	37	37	48	$7,282,400	$8,200,744	$11,354,609
TX	21	28	45	$4,353,693	$5,229,842	$11,027,766
PA	18	21	34	$3,807,542	$2,413,736	$8,366,580
NC	18	12	17	$4,776,849	$2,777,792	$5,046,216
NY	17	28	32	$4,307,375	$7,315,705	$6,174,246
AZ	16	11	19	$2,979,729	$3,276,027	$5,080,288
OH	15	28	31	$3,127,673	$4,701,354	$5,367,008
CO	15	19	42	$3,860,084	$2,176,193	$9,404,372
IL	14	10	17	$3,478,217	$2,880,517	$3,619,707
NJ	13	10	12	$2,810,587	$2,144,132	$2,431,501
MD	12	17	28	$3,439,760	$2,783,943	$6,501,183
WA	12	12	22	$3,131,867	$1,969,011	$3,045,089
MI	12	8	31	$2,625,785	$2,675,296	$6,591,129
FL	11	15	29	$2,249,752	$2,291,590	$7,764,217
GA	9	13	16	$1,287,045	$2,048,787	$4,182,343
AL	9	11	12	$2,509,542	$1,646,215	$3,881,029
CT	8	10	17	$1,656,410	$2,454,421	$4,828,527
MN	7	7	11	$659,429	$2,867,171	$2,664,183
TN	7	7	5	$1,631,232	$1,192,845	$2,399,190
NM	5	7	13	$1,269,707	$1,432,485	$2,543,532
MO	5	2	8	$1,544,862	$269,167	$2,242,068
OR	4	6	10	$949,349	$539,220	$2,548,808
OK	4	5	1	$768,978	$1,767,939	$100,000
SC	4	1	7	$880,515	$99,946	$2,081,002
WI	3	6	10	$1,027,032	$588,551	$3,259,939
MT	3	6	4	$405,390	$1,558,386	$1,449,954
UT	3	3	6	$558,173	$764,099	$995,728
KY	3	2	7	$627,151	$200,000	$851,631
DE	3	2	6	$298,736	$299,690	$2,047,527
SD	3	1	2	$238,402	$99,968	$599,385
VT	3	1	1	$564,286	$499,919	$99,039
NH	2	4	5	$1,079,911	$1,139,710	$503,021
NV	2	3	9	$198,585	$269,476	$1,606,411
IN	2	3	8	$280,607	$277,444	$3,534,859
WY	2	3	1	$568,539	$275,256	$749,967
ND	2	1	3	$199,000	$98,291	$1,349,650
HI	2	0	2	$599,873	$0	$1,201,073
MS	1	2	3	$70,000	$198,986	$697,457
AR	1	2	2	$99,972	$200,000	$858,369
IA	1	1	3	$497,524	$133,750	$299,651
KS	1	1	3	$100,000	$750,000	$269,957
WV	1	1	3	$68,546	$1,176,430	$264,994
ME	1	1	0	$99,900	$500,000	$0
LA	0	2	2	$0	$599,055	$169,392
ID	0	1	2	$0	$99,999	$849,911
NE	0	1	2	$0	$99,840	$199,510
RI	0	1	1	$0	$99,000	$750,000
AK	0	0	0	$0	$0	$0

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